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QUATERNARY GEOLOGY OF GLENLYON MAP AREA (105L), YUKON TERRITORY

BY

BRENT CHRISTOPHER WARD ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

DEPARTMENT OF GEOLOGY

Edmonton, Alberta
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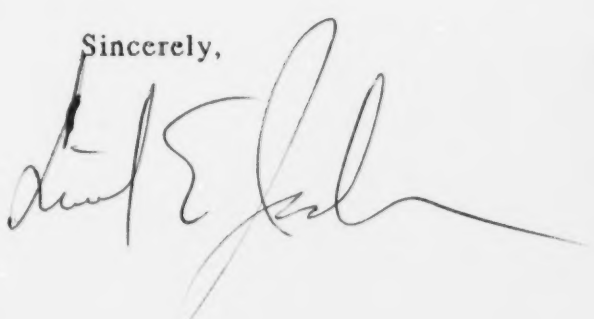

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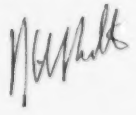

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Dr. P. Erdmer

Dr. C. Schweger

Dr. T.F. Moslow

Dr. I.A. Campbell

Dr. R. Fulton

For Lorraine

ABSTRACT

Regional Quaternary surficial mapping, stratigraphic studies and sedimentological studies were undertaken in Glenlyon map area (105L) and stratigraphic studies were extended westward into Carmacks map area (115I), central Yukon Territory.

Surficial sediments were divided into twenty-three units which range in age from Early Pleistocene to Holocene. There is evidence for at least three glaciations: pre-Reid, Reid and McConnell of Early Pleistocene, Illinoian and Late Wisconsinan age, respectively. The deposits of the pre-Reid glaciation(s) have a very subdued surface morphology. The Reid glaciation was less extensive and has better preserved landforms than the pre-Reid glaciation(s). Mid Wisconsinan organic beds were identified at the Granite Canyon section; insect macrofossils and pollen indicate forested conditions at 36,000-37,000 yr BP. The landforms and sediments of the McConnell glaciation are well preserved, and allow for better reconstruction of conditions than the previous glaciations. The area was affected by the Selwyn and Cassiar lobes of the Cordilleran Ice Sheet, and with many areas as nunataks, flow of the ice sheet was strongly controlled by topography. A thick sequence of sands below McConnell till at Section 26 suggests rivers aggraded during ice advance. A study of sediments at the Safety Pin Bend section points to an oscillation of the ice front, likely during advance.

Airphoto analysis, identification of erratics, and stratigraphic and geomorphic investigations were used to determine the nature of the McConnell glaciation in the Glenlyon Range. Because of aridity, local cirques only supported small glaciers which did not contribute to the Selwyn Lobe.

McConnell deglaciation was very rapid and the ice sheet downwasted and stagnated in place, indicating a rapid rise in the firn line. Deglacial sedimentation along the Pelly River was very complex. Material was deposited in many small lake basins, in many places on top of stagnant ice. Sediment appears to have been derived from the active ice margin, stagnant ice, marginal streams, and recently deglaciated valley sides.

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The writer benefited from discussions with C. Burn, J. Clague, A. Duk-Rodkin, R. J. Fulton, O. L. Hughes, S. R. Morison, and C. A. S. Smith, and the entire Quaternary Research Group at the University of Alberta, especially P. T. Bobrowsky, N. Catto, T. Giles, J. Kulig, V. Levson, D. Liverman and M. Reasoner. A. Duk-Rodkin had previously mapped some of the glacial limits in the Glenlyon map area and made her airphotos available. S. Morison provided notes of his field observations along the Yukon River in 1979. C. Schweger and H. Friebe aided in the processing and identification of pollen. J. Matthews and A. Telka identified insect macrofossils. Grain size data was provided by P. Lindsay. Portions of this thesis were written while visiting the Geology Department at the University of Bergen, and thanks are extended for support during this time.

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CHAPTER 1 - INTRODUCTION

The first observations on the glacial geology of central Yukon were by G.M. Dawson of the Geological Survey of Canada, who reported on bedrock and surficial geology during a descent of the Pelly River in 1887 (Dawson, 1888). Continuing in this tradition, most of the advances in knowledge of the glacial history of the area have been by the Geological Survey of Canada. The glacial stratigraphic framework was developed by H. Bostock (1966) and refined by O. L. Hughes and various colleagues (Foscolos *et al.*, 1977; Hughes, 1987; Hughes *et al.* 1969, 1972, 1983, 1987; Rutter *et al.*, 1978; Smith *et al.*, 1986; Tarnocai *et al.*, 1985) and is based on morphostratigraphic, stratigraphic, and geomorphic evidence. Four glaciations were identified which, from oldest to youngest are Nansen, Klaza, Reid and McConnell, with the older advances being the most extensive.

This study documents the Quaternary geology of the Glenlyon map area (105 L) and portions of the Carmacks map area (115K). This area includes the westernmost limit of the Cordilleran Ice Sheet during the McConnell and Reid glaciations. Many of the upland areas were nunataks above these glaciations, preserving deposits of older glaciations. The study area was chosen for the following reasons: its location at the westernmost limit of the last two known glaciations in the central Yukon could result in the preservation of a long stratigraphic record; and because only limited Quaternary studies had been done before (eg. Campbell, 1967; Klassen *et al.*, 1987).

The specific objectives of this study are: 1) to produce four 1:100,000 scale surficial geology maps; 2) to document the Quaternary stratigraphy and to trace this stratigraphy into the westerly adjacent Carmacks map area (115K) and to use these data to reconstruct a geological history of the area; 3) to

examine the nature of glaciation of the area in order to determine if local glaciers contributed to the Cordilleran Ice Sheet; and 4) to examine the nature of sedimentation during deglaciation.

The results of these objectives are presented and discussed in Chapters 2 through 4 and the main conclusions are summarized in Chapter 5. Chapter 2, with the accompanying maps, gives a more general overview of the Quaternary geology than Chapters 3 and 4. The map units, the basis for their subdivision, their lithological range and their distribution, are described. The stratigraphy of sediments, both exposed at the surface and in sections, is documented. From these data a geologic history for the area is given.

Chapter 3 focuses in on a more specific topic: the nature of glaciation of the Glenlyon Range. Glenlyon Range was inundated by the Cordilleran Ice Sheet, but the extent of local glaciers was unclear. By examining sections and airphotos and by tracing distinctive erratics, the amount of interaction of local ice and the Cordilleran Ice Sheet was determined.

Chapter 4 examines the sediments produced during deglaciation along the Pelly River. Deglaciation of the Cordilleran Ice Sheet was by regional stagnation. Dams of stagnant ice, aided by isostatic depression, formed abundant glacial lakes which received large thicknesses of sediment. Much of this sediment was deposited above and adjacent to stagnant ice, resulting in structurally complex, glaciolacustrine deposits. These sediments are divided into facies, interpreted and placed into a depositional framework to explain sedimentation along the Pelly River.

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CHAPTER 2 - SURFICIAL MAPPING AND QUATERNARY STRATIGRAPHY OF GLENLYON MAP AREA (105L), YUKON TERRITORY*

*A version of this chapter has been submitted for publication. Ward, B. (in review) Geological Survey of Canada Memoir

INTRODUCTION

General Statement

Surficial mapping and geological studies were conducted in the Glenlyon map area (105 L), located in central Yukon between 62° and 63° N and 134° and 136° W. Stratigraphic studies were also carried out westward along the Pelly River into the adjacent Carmacks map area (115I) (Fig. 2-1, 2-2) in which the limits of the last two glaciations are located.

Physiography

The Glenlyon map area is located within the broad physiographic regions of the Kaska Mountains and the Yukon Plateaus (Mathews, 1986) (Fig. 2-3). The Kaska Mountains consist of the Glenlyon Range, the northwesternmost extension of the Pelly Mountains (Fig. 2-3). Peaks above 2000 m in elevation occur within the Glenlyon Range (Fig. 2-4). The Yukon Plateaus are a broad upland area consisting of low, rolling hills and some mountain ranges, notably the Macmillan, Kalzas, Big Salmon, Little Salmon, and Wilkinson ranges. Peaks with elevations in excess of 1700 m occur within these ranges, but the Yukon Plateaus generally has elevations of 600 to 1200 m.

The Yukon Plateaus are incised by several valleys. The largest valley is the Tintina Trench (Plate 2-1), a linear, structurally controlled depression that trends across Yukon from northwest of Watson Lake into Alaska (Fig. 2-3). In the Glenlyon map area, the Tintina Trench is 4 to 10 km wide and lies below 600 m above sea level (asl). It contains Detour Lakes, Little Kalzas River and Little Kalzas Lake, and segments of the Pelly River. Other main valleys in the area are those containing the Macmillan River, Earn Lake, the headwaters of the Tummel

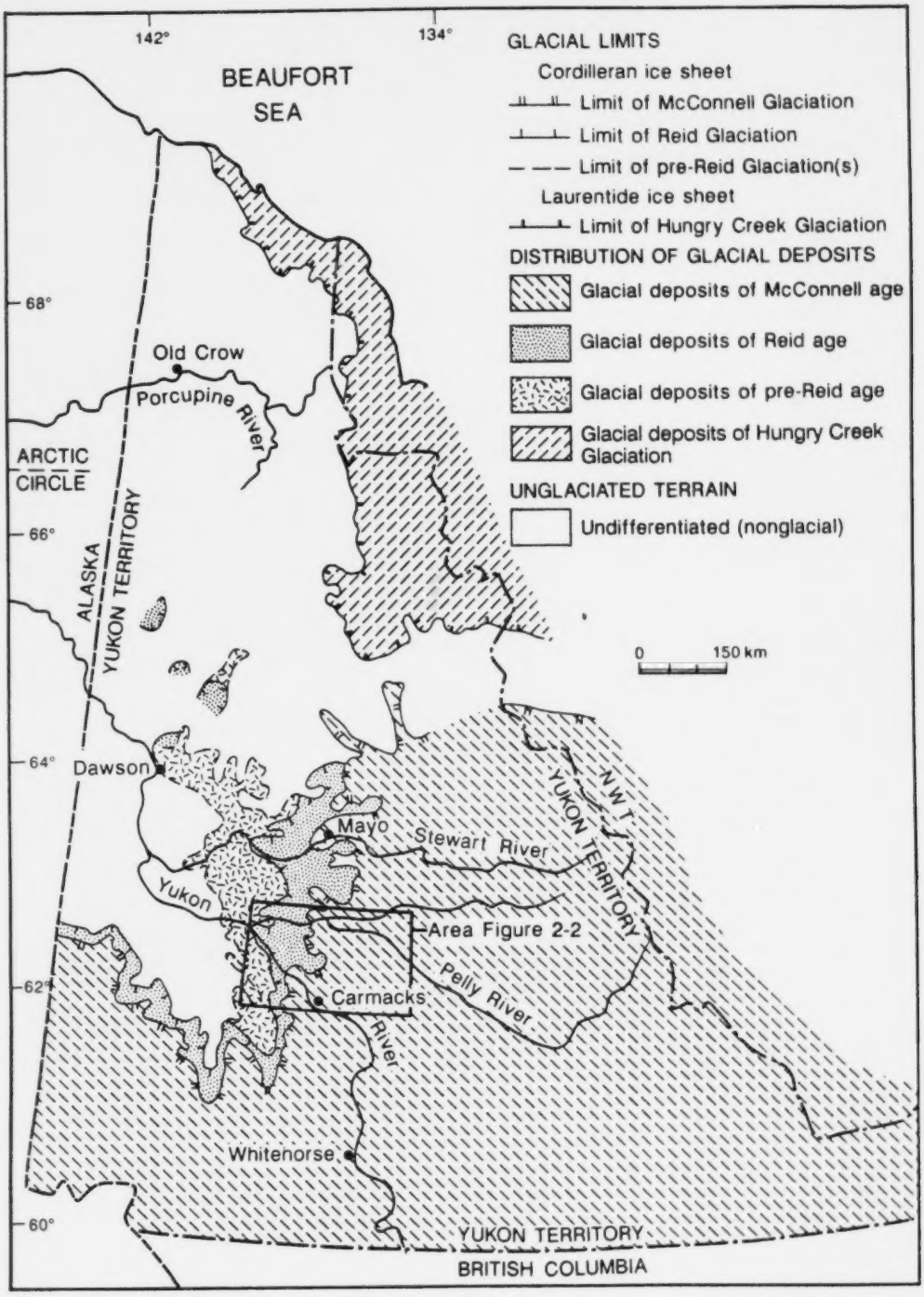


Figure 2-1: Glacial limits in Yukon Territory. Location of Fig.2-2 indicated Modified from Tarnocai and Schweger (1991, Fig. 1)

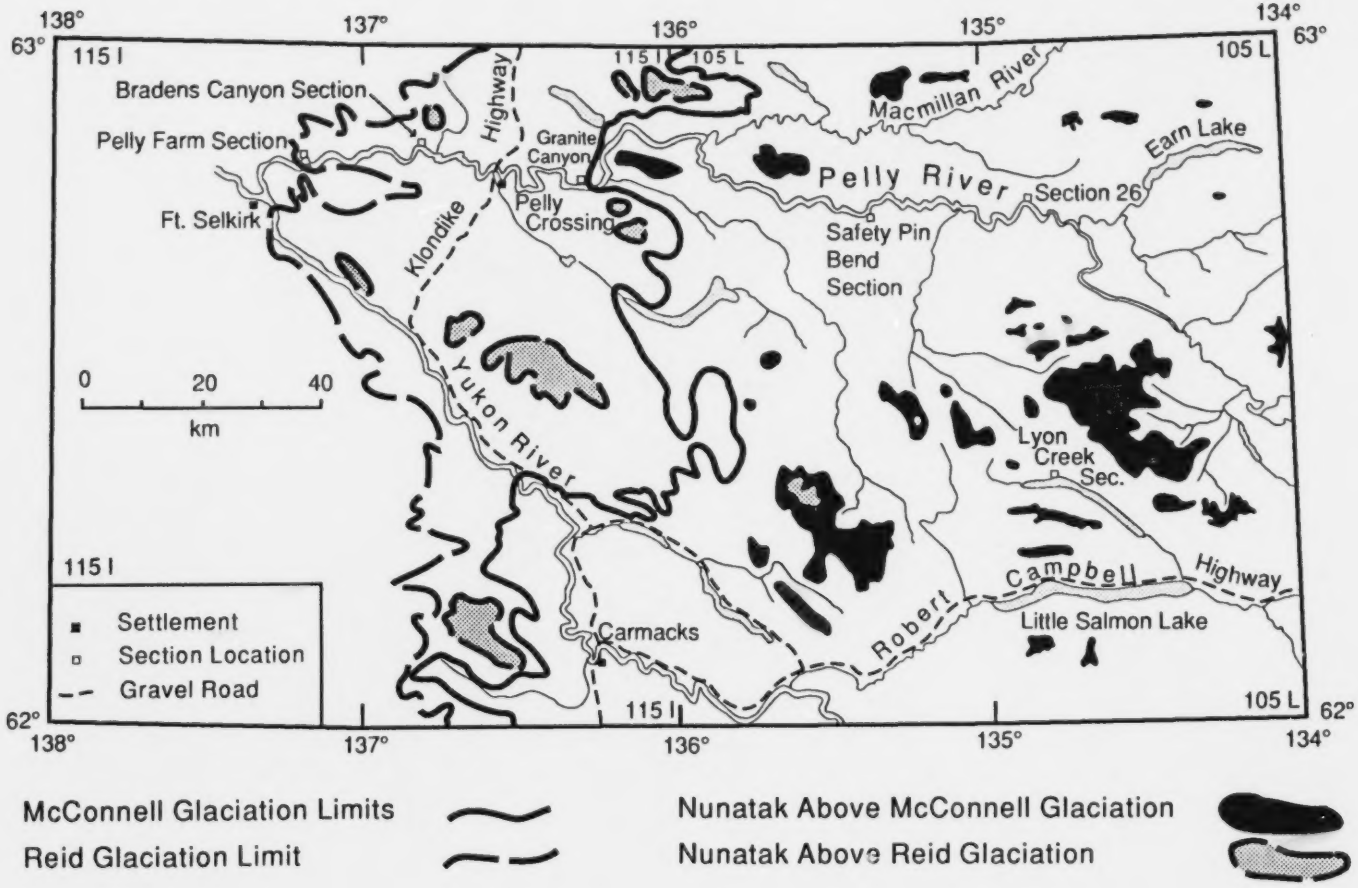


Figure 2-2: Glenlyon map area (105L) and portion of Carmacks map area (115I) showing glacial limits, nunataks and sections mentioned in the text. Modified from Duk-Rodkin et al. (1987, Fig. 28.1)

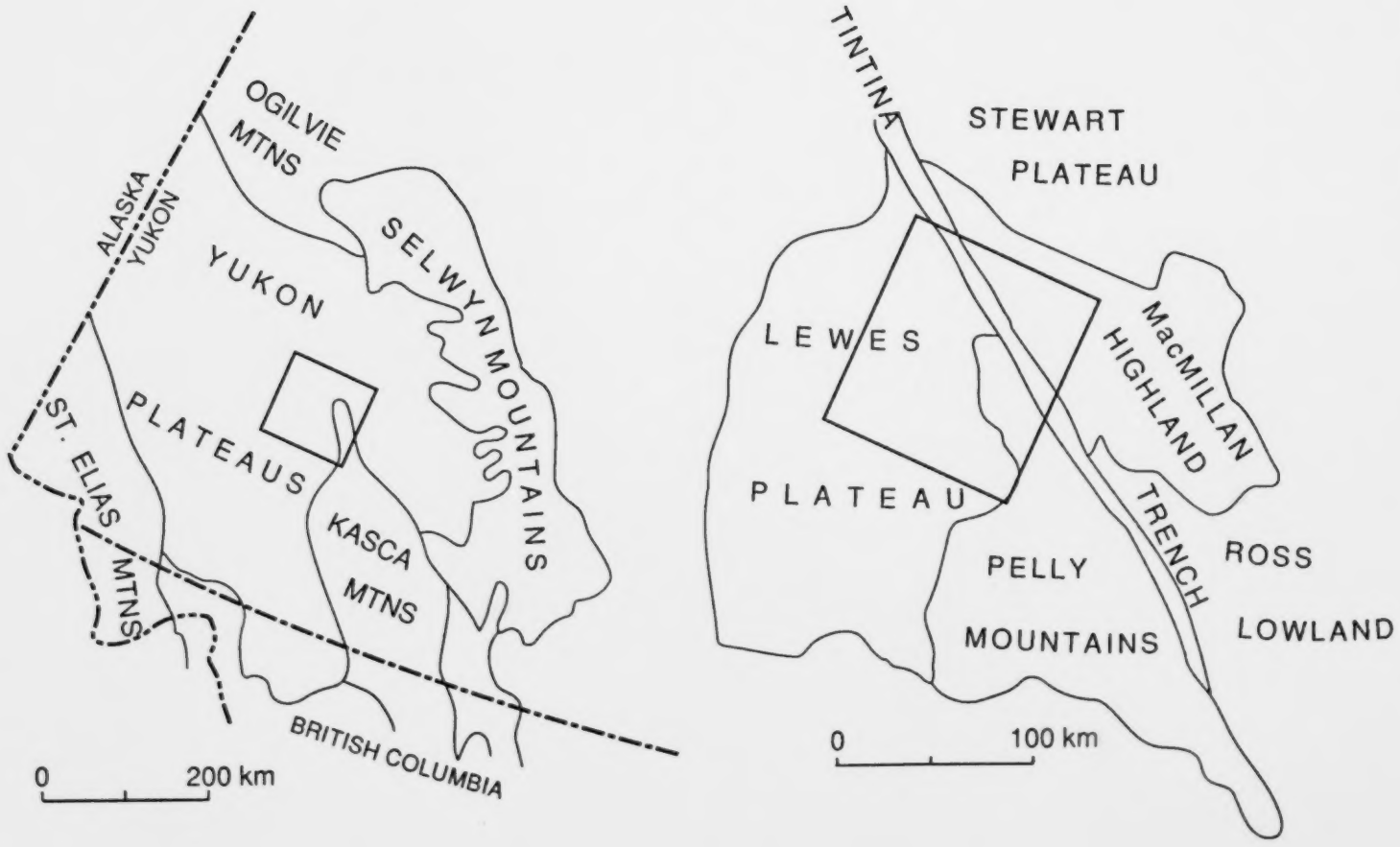


Figure 2-3: Major physiographic regions of southern Yukon (Modified from Mathews, 1986). Glenlyon map area shown by rectangle.

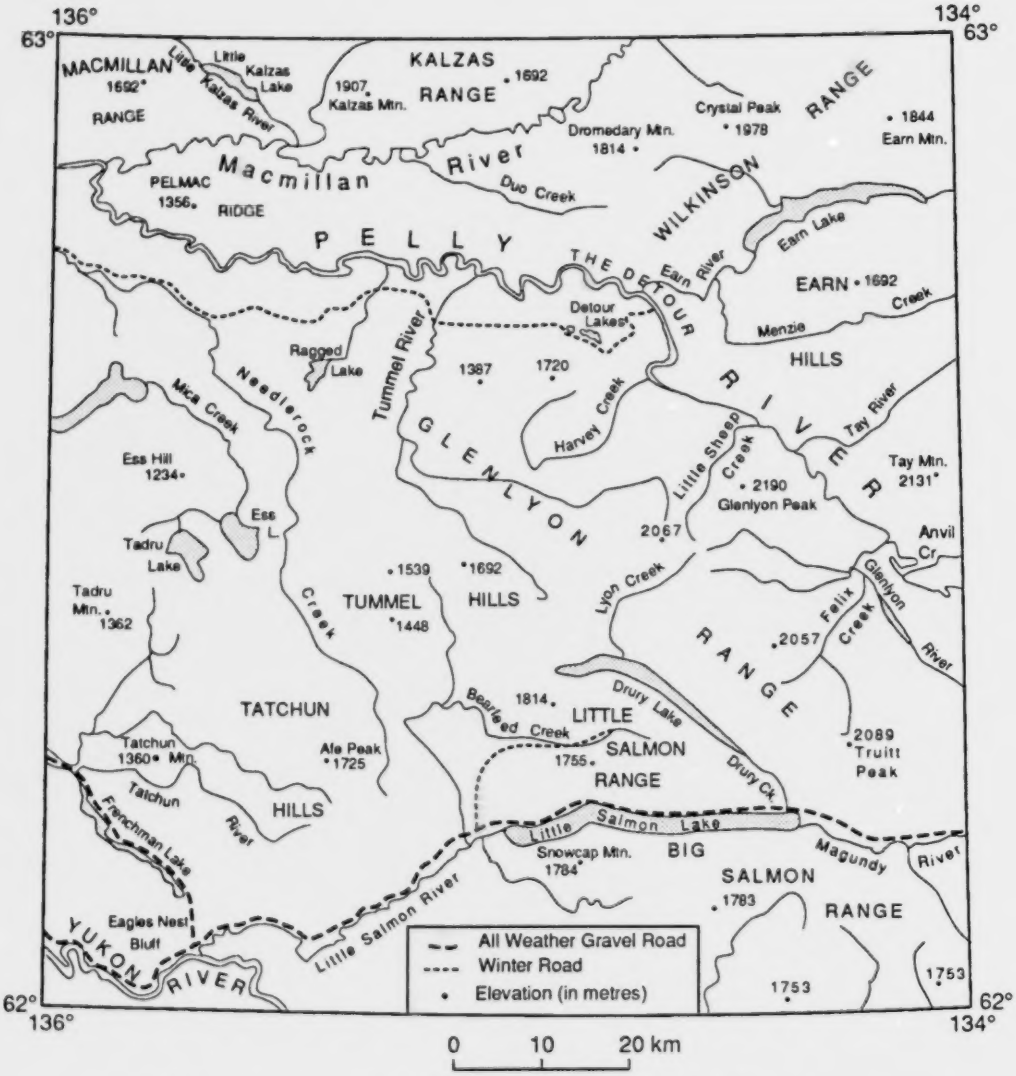


Figure 2-4: Location map of physiographic features in the Glenlyon map area.

Plate 2-1: View southeast along Tintina Trench from Anvil Creek, near the eastern edge of the map area. Map 1789A.

River and Drury Lake, the Little Salmon River and Little Salmon Lake, the Yukon River, and Frenchman Lake.

Drainage

The entire study area is part of the Yukon River drainage system. The Yukon and Little Salmon rivers drain the southern third, and the Pelly River and its tributaries drain the northern two-thirds of the map area. The Macmillan River, the largest tributary of the Pelly River, flows along the northern edge of the map area. Other notable tributaries are the Tummel, Earn, Tay and Glenlyon rivers. This drainage system terminates to the west in the Bering Sea.

Discharge, freeze up and break up data have been recorded for the Pelly River. At the Pelly Crossing gauging station the river has an average daily discharge of 394 m^3/s and a maximum recorded discharge of 4304 m^3/s (Inland Waters Directorate, 1984). Average freeze-up of the Pelly River occurs on October 28 and break-up on May 12.

River morphology in the Glenlyon map area ranges from meandering and braided-meandering to braided with occasional anastomosing reaches. Most of Macmillan River meanders with few mid-channel bars. The Pelly River and the short segment of the Yukon River in the map area can be classified as braided-meandering; they have a single dominant channel with many mid-channel bars and abundant secondary channels. The Pelly and Macmillan rivers contain anastomosing reaches in areas where the banks consist of very fine grained glaciolacustrine sediments and are relatively stable. Braided streams are common in mountainous areas where steep gradients and flashy discharge cause channels to shift frequently.

Drainage Evolution and Anomalies

Tectonics have had a marked effect on drainage pattern evolution. Tempelman-Kluit (1980) proposed that the southern Yukon basin drained southwest to the Pacific in mid-Tertiary time. He further suggested that the drainage began to shift to the northwest due to differential uplift of the St. Elias Mountains in the late Tertiary. A complete shift would have occurred sometime after the advent of glaciation as ice in the St. Elias Mountains would have blocked drainage to the southwest.

Other glacial induced modifications to the drainage system are apparent. U-shaped valleys (Plate 2-1) resulting from glacial scouring and glacially over-deepened valleys which now contain lakes, such as Little Salmon and Drury lakes, are common. In addition, the presence of underfit streams in many valleys indicate that glacial meltwater has modified the drainage. This modification can occur when meltwater follows pre-existing streams, eroding and enlarging valleys, or when meltwater scours new valleys.

Preglacial drainage modified by glaciation has resulted in significant drainage anomalies of large and small scale. Large-scale anomalies are the result of tectonism and multiple glaciation. Examples of these types of anomalies are the deflection of the Pelly River out of the Tintina Trench and the possible deflection of the Yukon River out of the valley now occupied by Frenchman Lake. Both of these examples can be explained by glacial blockage and diversion which likely occurred prior to the Late Wisconsinan glaciation.

Many small-scale drainage anomalies were created during the Late Wisconsinan glaciation and the Holocene. Stagnant ice caused shifts of the Pelly and Little Salmon rivers at the end of the Pleistocene. The Detour, along the Pelly River, begins at the mouth of Harvey Creek, where the river bends

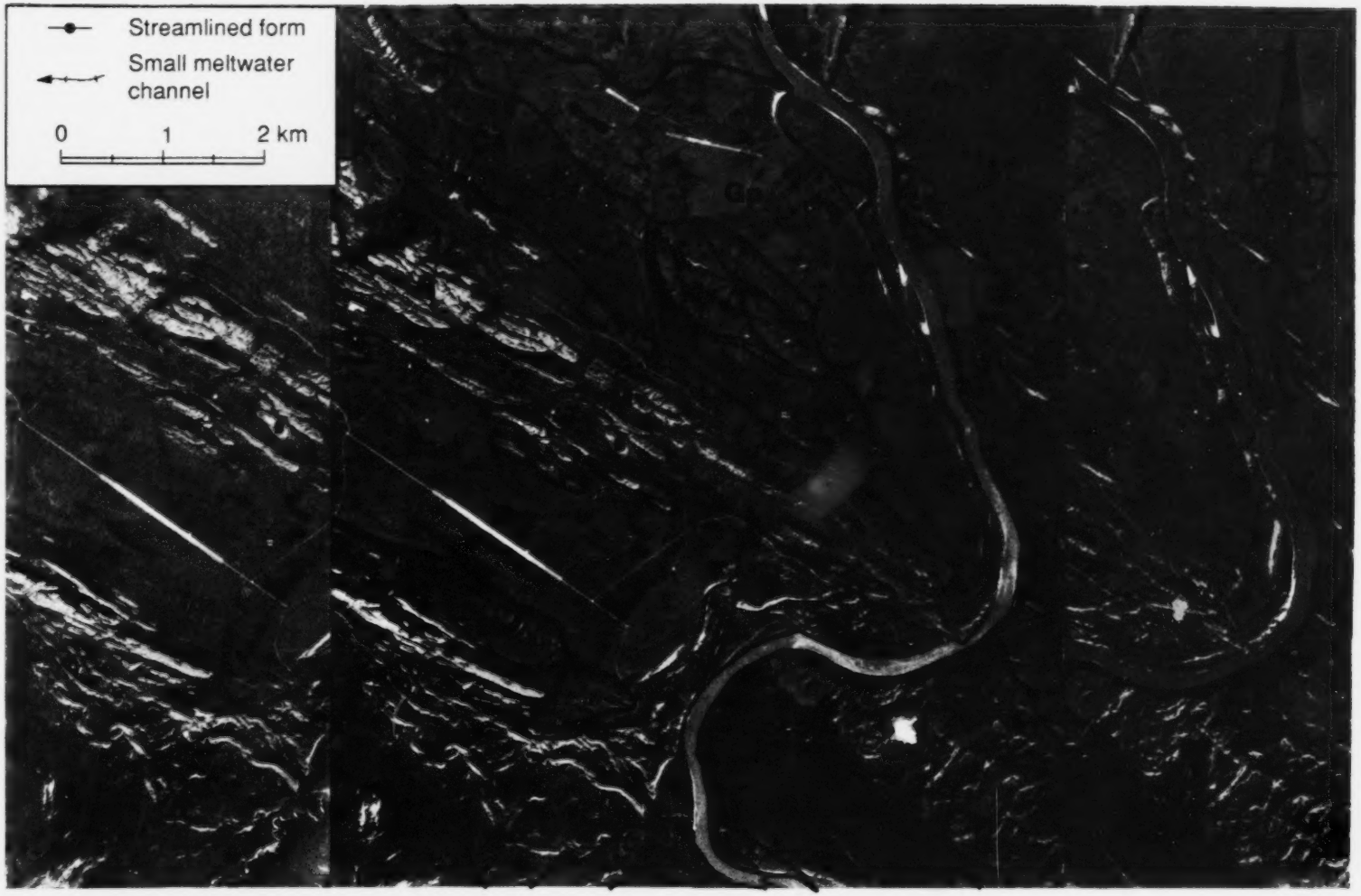
abruptly to the northwest, then gradually curves to the northeast around a bedrock high to rejoin the Tintina Trench (Fig. 2-4, Plate 2-2). Detour Lakes, which occupy depressions left by melting ice, occur along the old course of the river (Fig. 2-4). As suggested by Campbell (1967, p. 20), this stagnant ice blocked drainage, forming a large glacial lake. When the lake drained, likely near the outlet of the Earn River, the Pelly River became entrenched and abandoned its old course. A similar scenario was proposed for the Little Salmon River by Campbell (1967, p. 20). Again, ice blocked the drainage and deflected the river to the northwest, around a bedrock high, and then to the southwest to the Yukon River.

An example of post-glacial stream capture is found at the headwaters of Harvey Creek. The course of Harvey Creek almost circumscribes a bedrock high (Fig. 2-4). The short segment flowing southwest previously flowed into the Tummel River. Glacial erosion and meltwater action formed a meltwater channel between Harvey Creek and Tummel River. An alluvial fan has developed where the southwestward flowing headwaters enters the meltwater channel, diverting it into the Harvey Creek drainage.

Climate, Soils and Vegetation

The climate of Yukon is classified as sub-Arctic Continental (Wahl *et al.*, 1987). It is characterized by long, cold winters and short, mild summers. Yukon is divided into 9 climatic regions and two of these are found in the map area: the Pelly-Cassiar Mountains; and the Central Yukon Basin (Wahl *et al.*, 1987). These climatic regions correspond generally to the physiographic regions of the Kaska Mountains and the Yukon Plateaus, respectively. The Pelly-Cassiar climatic region has higher winter temperatures, cooler summers and more precipitation, especially in winter, than the Central Yukon Basin climatic region. Records from meteorological stations at Drury Creek, in the

Plate 2-2: Ice stagnation complex (Gx) along the Pelly River at The Detour, near the Earn River, Map 1787A. Detour Lakes occur just to the east of the area shown. Also present are glaciofluvial plain (Gp), glaciofluvial terrace (Gt), morainal veneer and blanket (Mv, Mb), alluvial terrace (At), alluvial plain (Ap), alluvial complex (Ax), colluvial apron (Ca), bedrock (R). (National Air Photo Library A20059 167, 168 and 169)


Streamlined form
Small meltwater channel
0
1
2 km

Pelly-Cassiar Mountains Region, and Carmacks, in Central Yukon Basin Region, give a reasonable approximation of the climate of the area (Table 2-1). However, since the Drury Creek station is located in a valley, conditions at higher elevations in the Pelly-Cassiar Mountains Region are probably more similar to those at Anvil (Table 2-1) in the Anvil Range, 50 km to the northeast .

The Glenlyon map area is in the widespread discontinuous permafrost zone (Brown, 1978). Permafrost is common on north-facing slopes and in fine-grained material. Segregated ice is common in glaciolacustrine sediments exposed along the Pelly and Macmillan rivers. Ice wedges were observed at two sites along the Pelly River in fine grained fluvial overbank deposits overlain by thick organic deposits. Retrogressive thaw slides are common where stream erosion, forest fire or anthropogenic disturbance, such as road building, has exposed ice rich sediments.

Most soils in the Glenlyon map area fall into subgroups of the Brunisolic or Cryosolic soil orders (ACECSS, 1987). Mountainous areas consist mainly of Eutric Brunisols with occasional Turbic Cryosols. Well drained plateaus and valleys contain both Dystric and Eutric brunisols, while poorly drained areas contain Cryosols and Organic soils; the latter are commonly associated with peat accumulations (Tarnocai, 1987). Regosols occur throughout the map area on fresh or unstable surfaces. Soils examined in detail at studied sections in the valleys are Eutric Brunisols, similar to the Stewart neosols described by Tarnocai *et al.* (1985), Smith *et al.* (1986) and Tarnocai (1987).

Vegetation varies with elevation, aspect and forest fire frequency. Tree line is approximately 1500 m in the Glenlyon Range and descends gradually to 1370 m or slightly lower in the western part of the map area. Forests are dominated by *Picea* (spruce) and contains minor *Salix* (willow), *Populus* (poplar) and *Pinus* (pine). *Picea glauca* (white spruce) and *Populus* generally

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
CARMACKS													
62° 6'N 136° 18'W 523 m													
NTS 115I													
Daily Temperature (C)	**-28.2**	**-19.4**	**-11.6**	**-0.1**	**7.1**	**12.5**	**14.5**	**12.4**	**6.7**	**-2.0**	**-13.8**	**-24.0**	**-3.8**
Extreme Maximum Temperature	6.0	12.8	14.4	23.4	25.0	35.0	31.7	31.3	26.7	18.3	12.8	5.6	35.0
Extreme Minimum Temperature	-57.8	-57.2	-50.0	-31.1	-12.2	-3.9	-1.1	-5.0	-15.6	-28.9	-46.7	-54.4	-57.8
Rainfall	0.0	0.0	0.2	0.7	12.9	37.5	42.3	34.6	23.3	5.5	0.7	0.0	157.7
Snowfall	17.6	10.7	9.4	7.1	1.8	0.0	0.0	0.0	1.3	12.8	17.1	17.2	95.0
Total Precipitation (mm)	**18.4**	**12.5**	**10.6**	**7.2**	**15.5**	**37.4**	**42.3**	**34.1**	**25.1**	**17.7**	**18.6**	**14.9**	**254.3**
DRURY CREEK													
62°12'N 134° 23'W 609 m													
NTS 105L													
Daily Temperature (°C)	**-23.7**	**-16.5**	**-9.9**	**0.0**	**6.6**	**12.1**	**14.3**	**11.8**	**6.8**	**-0.8**	**-11.1**	**-19.7**	**-2.5**
Extreme Maximum Temperature	7.0	7.8	9.4	22.2	22.8	30.0	30.6	30.6	25.6	16.7	11.1	6.7	30.6
Extreme Minimum Temperature	-54.4	-46.1	-41.7	-28.9	-8.3	-2.8	-1.7	-2.8	-15.0	-25.6	-37.8	-51.1	-54.4
Rainfall	0.0	0.3	0.1	1.3	12.1	27.8	41.7	33.2	38.7	14.0	13.3	0.4	182.9
Snowfall	25.0	29.6	21.9	15.0	1.4	0.1	0.0	0.0	0.8	17.2	28.8	35.9	175.7
Total Precipitation (mm)	**25.6**	**29.3**	**23.0**	**15.8**	**13.7**	**28.0**	**41.7**	**33.2**	**38.8**	**31.3**	**32.9**	**36.1**	**349.4**
ANVIL													
62° 22'N 133° 23' 1158 M													
NTS 105K													
Daily Temperature (°C)	**-19.8**	**-13.9**	**-11.2**	**-3.2**	**4.0**	**9.9**	**11.5**	**9.5**	**4.6**	**-3.1**	**-11.6**	**-17.2**	**-3.4**
Extreme Maximum Temperature	5.0	9.4	8.0	15.5	20.0	29.4	28.9	26.7	25.0	14.4	11.1	5.6	29.4
Extreme Minimum Temperature	-46.6	-43.3	-41.1	-26.5	-14.0	-6.0	-3.3	-7.2	-15.6	-32.2	-39.4	-43.9	-46.1
Rainfall	0.0	0.2	0.0	0.5	10.2	34.8	45.6	41.6	29.6	2.6	0.1	1.2	166.9
Snowfall	27.7	16.7	18.3	10.7	13.1	0.0	0.0	0.7	3.8	29.5	30.9	27.8	179.2
Total Precipitation (mm)	**26.0**	**22.4**	**30.4**	**15.5**	**16.3**	**41.6**	**49.6**	**41.5**	**32.9**	**36.9**	**29.2**	**24.6**	**367.7**

Table 2-1: Selected climactic data for Carmacks, Drury Creek and Anvil (Whal et al. 1987).

indicate well drained conditions; *Picea marianna* (black spruce) generally indicate poorly drained conditions, which are commonly the result of permafrost. Recent forest fire scars contain an abundance of successional species such as *Populus*, *Alnus* (alder), *Betula* (birch), and *Salix*, as well as pine and spruce.

Population and Industry

Very few people live year round in the Glenlyon map area. Most of these residents live along the Robert Campbell Highway, mainly in the vicinity of Little Salmon Lake and at the Drury Creek Highway Maintenance Station. Little Salmon, a former small village, at the junction of the Little Salmon and Yukon rivers, is now abandoned. North of the Highway, scattered cabins, outfitters establishments, and fishcamps are inhabited seasonally.

Present industry is limited to a highways maintenance camp at Drury Creek, trophy and subsistence hunting and fishing, and trapping. Several power dam sites have been proposed for the Glenlyon map area, but none are currently being pursued; proposed sites include The Detour along the Pelly River, Eagle Nest Bluff along the Yukon River, and Drury Lake.

Extensive mineral exploration has occurred in the past but presently there are no plans for mineral development in the area. Exploration has concentrated on base metals such as copper, lead, and zinc, although some claims also contain silver. As well, several barite sites have been staked. A complete listing of claims that have been staked can be found in Yukon Minifile, Northern Cordilleran Mineral Inventory (1990). The locations of the most important claims are shown in Fig. 2-5. Most activity has been concentrated along the Tintina Trench and in adjacent areas, with some activity in the vicinity of Little Salmon Lake. Prior to 1965 very few claims had

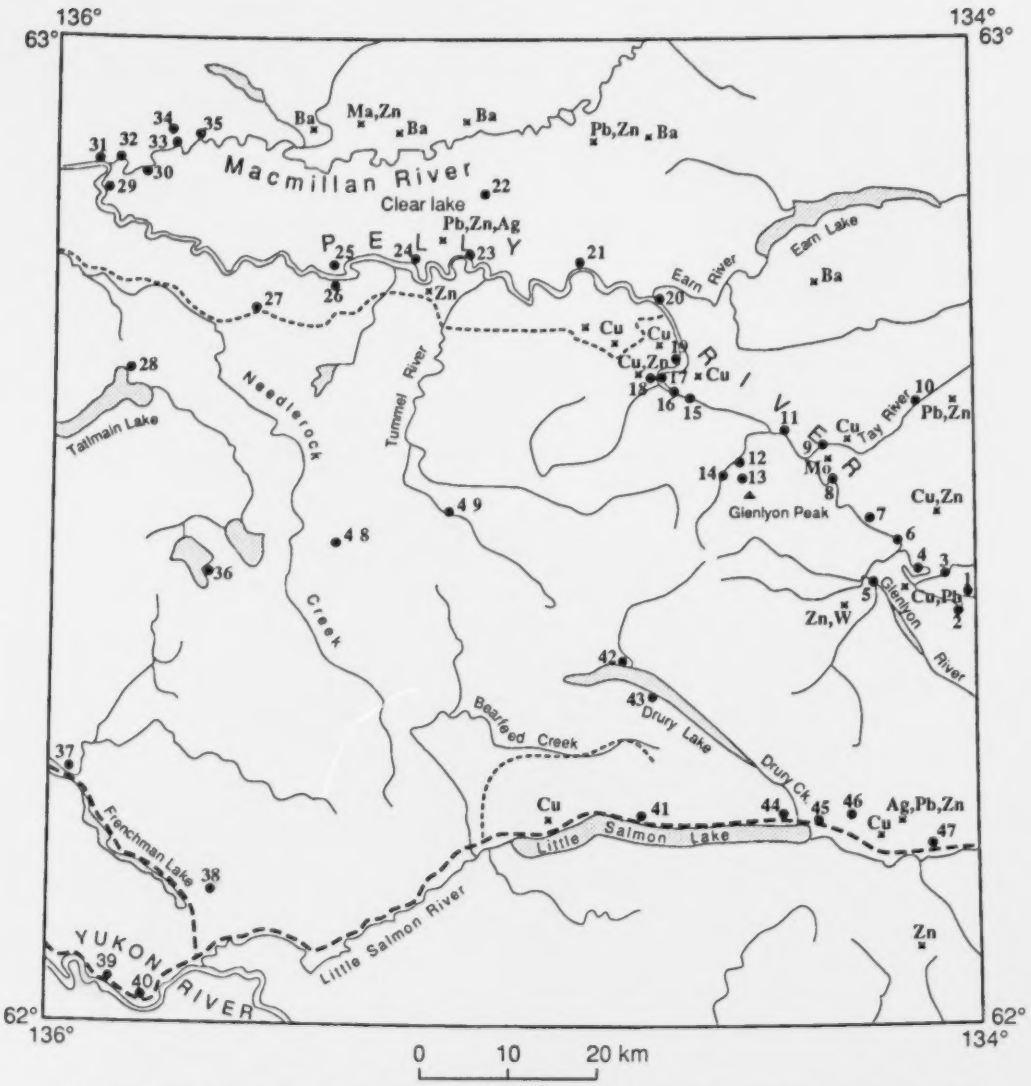


Figure 2-5: Sediment sample sites and selected mineral claims (Yukon Minifile, 1990). The most important elements for each claim are indicated.

been staked. However, in late 1965 and in 1966 there was a surge of activity in response to the discovery of the Faro lead-zinc orebody which is located 30 km east of the map area (Templeman-Kluit, 1981); at this time many copper, lead and zinc claims were staked along the Tintina Trench. Continued development of these sites and a minor upsurge in exploration in the mid-70s led to the discovery of the Clear Lake deposit in 1978. This deposit is located southwest of the Tintina Fault, just north of the Pelly River (Fig. 2-5). It is estimated to contain 25 million tonnes of massive pyritic mineralization, including galena and sphalerite, containing presently sub-economic concentrations of zinc, lead and silver. Exploration has been limited for most of the 80s although in 1989 several companies restaked many of the more promising claims as well as several new ones.

Previous Work

Recorded history and non-aboriginal exploration and settlement began in 1843 when Robert Campbell, an official of the Hudson's Bay Company, explored and named the Pelly River and many of its tributaries, including the Macmillan, Glenlyon, Tay, Earn, and Tummel rivers. The first bedrock and surficial geology observations in the area were by conducted by G.M. Dawson of the Geological Survey of Canada, who traveled down the Pelly River in 1887 (Dawson, 1889). This was followed by a description of bedrock and sediments along Macmillan River by McConnell (1903). He concluded that the last ice sheet did not cover all the peaks in the area. Cockfield (1929) examined the geology of the Little Salmon and Magundy valleys, and Johnston (1936) reconnoitered the Pelly River up-stream of Macmillan River. Although mainly concerned with the bedrock, both also made observations on the glacial history.

More detailed studies of the glacial history of the map area began in the 1960 's. Campbell (1967) mapped the bedrock of the Glenlyon map area in detail and also produced a glacial geomorphology map of the area. Using mainly airphoto interpretation, he mapped out the upper limit of the last ice sheet, delineated major ice flow directions, and indicated the interaction of two major lobes of the Cordilleran Ice Sheet, the Selwyn and Cassiar lobes (Campbell, 1967, Map 1222A). Duk-Rodkin *et al.* (1986) also used airphoto interpretation to construct a profile of the Selwyn Lobe during the McConnell glaciation.

Studies of volcanic rocks, drainage evolution and changes have also been undertaken in the map area. Grond *et al.*(1984) studied outcrops of the Carmacks Group volcanic rocks in the map area to determine whether they had continental or island arc affinities. Tempelman-Kluit (1980) based his ideas on the evolution of physiography and drainage in southern Yukon, in part, from the physiography of the map area. Recent changes in the Yukon River at Eagles Nest Bluff were studied by Fuller (1986).

Various Quaternary investigations have been carried out adjacent to the map area. Jackson (1987, 1989, in press) mapped surficial deposits and conducted stratigraphic studies in 5 map sheets to the east of the area (105 F, G, J, K, I) extending to the continental divide. Surficial mapping has also been carried out in map sheets immediately to the north (Hughes, 1983a, b), to the south (Klassen and Morison, 1987) (115I) and to the west (Klassen *et al.*, 1987) of the Glenlyon map area. Other stratigraphic studies include Jackson *et al.* (1990) who examined interbedded volcanics and glacial sediments to obtain relative ages on Early Pleistocene glaciations, Jackson and Harington (1991) who studied a mid-Wisconsinan mammal site, providing paleoenvironmental information as well as a maximum age on the Late

Wisconsinan glaciation and Matthews *et al.* (1990a) who examined sub-McConnell till sediments to provide paleoenvironmental information and also provided a maximum age.

Field and Laboratory Work

Access for geologic investigations was made possible by two roads and two rivers. The Robert Campbell Highway extends across the southern part of the map area, connecting Carmacks and Faro, (Figs. 2-2, 2-4) and another road in the southwest corner of the map area runs from the Robert Campbell Highway along Frenchman Lake to join the Klondike Highway. The Pelly and Macmillan Rivers allowed boat access to river sections. The rest of the region is not easily accessible but some areas were accessed by float plane and helicopter.

The area was reconnoitered in 1986. Field work was carried out mainly in the summers of 1987 and 1988, with limited investigations made in 1989.

Textural and Chittick analyses were completed under the direction of P. Higgins, Geological Survey of Canada. Radiocarbon ages were obtained from the Geological Survey of Canada (GSC), IsoTrace (TO); and Alberta Environmental Center Vegerville (AECV) under the direction of R. J. McNeely, R. P. Beukens, and L. D. Arnold, respectively.

BEDROCK AND TECTONICS

Bedrock

The bedrock of the Glenlyon map area is complex, and includes: North American strata, displaced North American strata, pericratonic terranes, accreted terranes and post-accretion strata (Wheeler and McFeely, 1991). The distribution of these strata is shown in Fig. 2-6. The reconnaissance geology

LEGEND

NORTH AMERICAN STRATA

Outer Detrital Clastics Carboniferous-Permian (**CP**)
Quartzose siltstone and chert

Earn Group Devonian-Mississippian (**DME**)
Chert pebble conglomerate, chert, argillite and quartzite

Volcanic rocks Devonian (**Dv**)
Tuff, flow and/or small intrusives

Anvil Range Group Cambrian-Ordovician (**€Ov**)
Basalt, tuff and breccia

Hyland Group Hadrynian-Cambrian (**P€H**)
Slate and quartzite

DISPLACED NORTH AMERICAN STRATA

Cassiar Terrane

Earn Group equilavent Devonian-Mississippian (**DMs**)
Quartzite, dolomite, slaty limestone and slate

Askin Group Cambrian(?)-Devonian (**€DR**)
Dolomite, limestone, quartzite and shale

Harvey Group Cambrian (**€H**)
Quartzite, schist, shale, phyllite and minor limestone

PERICRATONIC TERRANE

Yukon-Tanana Terrane

Nisutlin Terrane Upper Paleozoic-Triassic (**PTRN**)
Schist and gneiss

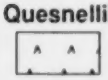
ACCRETED TERRANES

Stikinia

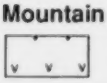
Laberge Group Lower-Middle Jurrasic (**JT**)
Conglomerates, greywacke, siltstone, shale and limestone

Tatlmain and Tatchun batholiths Late Triassic-early Jurrasic (**TRJg**)
Foliated hornblend granodiorite and quartz monzonite

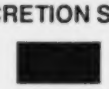
Quesnellia


Nicola Triassic-Jurrasic (**TRJN**)
Andesite, dacite and rhyolite

Slide Mountain Terrane


Devonian-Triassic (**DTRs**)
Andesite, basalt, basaltic greenstone, chert and tuff

POST-ACCRETION STRATA


Volcanic rocks Tertiary (**Tv**)
Bimodal suite of basalt and rhyolite

Granites Tertiary (**eT**)
Granodiorite and quartz diorite

Carmacks Group Upper Cretaceous (**uKc**)
Andesitic and basaltic flows

Granitic batholiths Mid Cretaceous (**mK**)
Various affinities Glenlyon Batholith (**mKgC**)

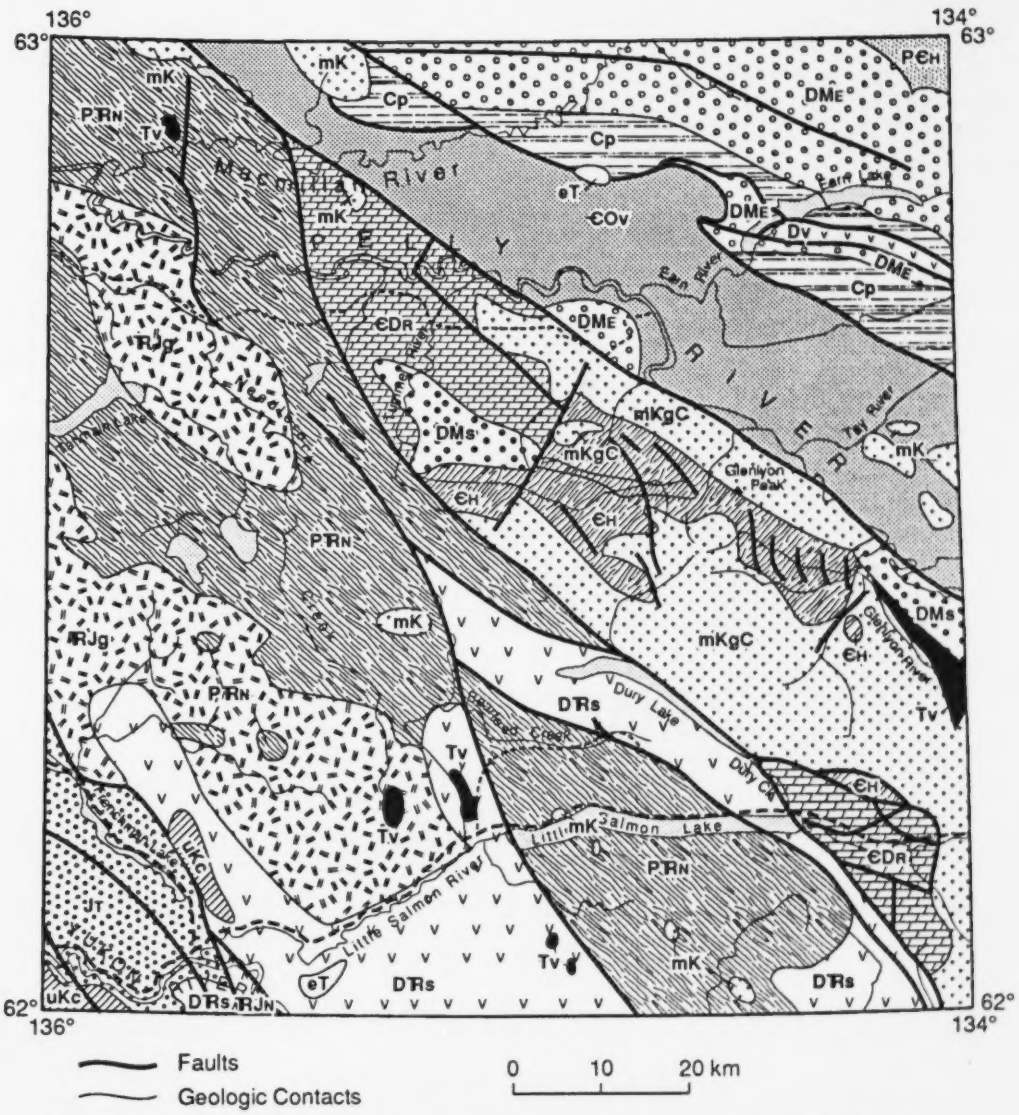


Figure 2-6:Bedrock geology of the Glenlyon map area. Modified from Campbell (1967), Gabrielse et al. (1980); Wheeler and McFeely (1991).

was done by Campbell (1967), but his work has been reinterpreted by subsequent workers in light of recent geologic theories of the tectonic evolution of Yukon (Gabrielse *et al.* 1980; Tempelman-Kluit 1979, 1981; Wheeler and McFeely, 1991). The following descriptions are based on the sources cited above as well as work in the adjacent Tay River and Quiet Lake map areas by Gordey and Erwin (1987).

North American Strata

North American strata consist of four major groupings of sedimentary and volcanic rocks deposited along the margin of ancestral North America. They range in age from Hadrynian to Permian, and were deformed during the Jura-Cretaceous, producing the northwest-trending thrust faults and folds of the Selwyn Fold Belt.

Displaced North American Strata (Cassiar Terrane)

Cassiar Terrane consists of rocks of North American affinity that have been displaced to the northwest along dextral strike-slip faults. The boundary between Cassiar Terrane and North American Strata is the Tintina Fault, the locus of at least 450 km of strike-slip displacement since the Upper Cretaceous. In the Glenlyon map area, Cassiar Terrane consists of sedimentary and metasedimentary rocks intruded by large mid-Cretaceous plutons. These rocks also have been deformed by north-west trending, Jura-Cretaceous thrust faults and folds.

Pericratonic Terrane (Yukon-Tanana Terrane)

Pericratonic terranes consist of rocks that differ in stratigraphic or structural characteristics from the ancient continental margin but have no

record of significant displacement. The Yukon-Tanana Terrane covers an extensive area in Yukon and Alaska. In the Glenlyon map area it is represented by the Nisutlin Terrane, sedimentary, volcanic and plutonic rocks that have been metamorphosed and intensely deformed. These rocks contain the Teslin Suture, a major geologic boundary marked by vertical to steeply dipping mylonite, schist, and gneiss. The deformation that produced the suture is thought to have occurred prior to the Middle Jurassic, during obduction of the exotic terranes (Hansen, 1990).

Accreted Terranes

The accreted terranes comprise obducted rocks that have no relation to the ancestral North American margin. They consist of rocks of oceanic and island arc affinities. Exotic terranes in the map area consist of Slide Mountain, Stikinia and Quesnellia.

Post-Accretion Strata

Post-Accretion strata are rocks deposited, extruded and emplaced after accretion of the exotic terranes. These strata include mid-Cretaceous and Tertiary plutonic rocks and Carmacks and Tertiary volcanic rocks.

Tectonics

The assemblage of rocks described above and their present distribution have been explained by accretion of distinct terrains onto the ancient North American margin, with associated deformation of rocks of the North American craton (Tempelman-Kluit, 1979, 1981; Gordey and Irwin, 1987; Wheeler *et al.*, 1988). The Jura-Cretaceous folding and faulting of the rocks along the North American margin occurred during obduction of the accreted terranes. This

was followed, in the mid-Cretaceous, by volcanism and plutonism which produced the Carmacks Group Volcanics and mid-Cretaceous plutonic suites of various affinities. During the Tertiary at least 450 km of strike slip movement occurred along the Tintina Fault, granitic rocks were intruded, and volcanic rocks were extruded.

Bedrock Controls on Physiography

Many of the major valleys that trend northwest-southeast follow faults and other major structural features (Fig. 2-6). Examples are the Tintina Trench which follows the Tintina Fault, and the depression occupied by Drury Lake and the headwaters of the Tummel River which follows the Teslin Suture.

REGIONAL QUATERNARY CONTEXT

The central Yukon has been repeatedly affected by the northernmost extension of the Cordilleran Ice Sheet. The glacial stratigraphy was developed by Bostock (1966) based on morphostratigraphic, stratigraphic, and geomorphic evidence; four glaciations were identified, from oldest to youngest these are the Nansen, Klaza, Reid, and McConnell advances. Each successive advance was less extensive than the preceding one (Fig. 2-1). Workers who have followed Bostock have been unable to differentiate the deposits and landforms of the two oldest glaciations, Nansen and Klaza, and thus, have included them under the term "pre-Reid" (Hughes *et al.*, 1969). Ages providing limits on these glaciations are listed in Tables 2-2, 2-3.

Recent stratigraphic and paleomagnetic work by Jackson (1989) and Jackson *et al.* (1990) in the Ft. Selkirk area has further confirmed at least two pre-Reid glaciations which are Early Pleistocene. Intercalation of glacial and

AGE	METHOD	REFERENCE	MATERIAL	SIGNIFICANCE
86 ± 8 ka	TL	(Wintle and Westgate, 1986)	Loess	Old Crow tephra
109 ± 14 ka	TL	(Berger, 1987)	Loess and tephra	Old Crow tephra
140 ± 10 ka	Isothermal fission track	Westgate et al., (1990)	Tephra	Old Crow tephra, provides a minimum age on Mirror Creek (Reid) glaciation and a maximum age for Koy-Yukon thermal event
~220 ka	Magnetic susceptibility	Beget and Hawkins, (1989)	Loess	Old Crow tephra
c. 80 ka	Uranium series	Hamilton and Bischoff, (1984)	Bone	Sheep Creek tephra
>150 ka	Stratigraphic position below Old Crow tephra	Westgate, personal communication, 1992	Loess and tephra in Fairbanks area	Sheep Creek tephra, provides a minimum on Reid glaciation and a maximum on fossils indicating boreal forest, Ash Bend section, Stewart River
REID GLACIATION				
YOUNGER PRE-REID				
1.35 ± 0.08, 1.35 ± 0.11, 1.47 ± 0.11 Ma	K-Ar, whole rock	Westgate, (1989)	Basalt	Basalts at Ft. Selkirk erupted during the younger pre-Reid glaciation
1.48 ± 0.19 Ma	Isothermal fission track, weighted mean	Westgate, (1989)	Tephra	Ft. Selkirk tephra, provides minimum on older pre-Reid glaciation.
OLDER PRE-REID				
1.60 ± 0.08 Ma	K-Ar, whole rock	Westgate, (1989)	Basalt	Basalts underlying older pre-Reid deposits at Ft. Selkirk, provides a maximum age.

Table 2-2: Ages for tephras and basalts mentioned in the text and their relationship to the Reid and pre-Reid glaciations.

AGE	LAB	REFERENCE	MATERIAL	SIGNIFICANCE
1250	GSC	Lerbekmo *et al.*, 1975	Various	White River tephra
6570 ± 610	AECV-483C	This paper	Peat	Pelly River 25m above present
7900 ± 120	AECV-844C	This paper	Peat	Paleosol between units 4 and 5, Bradens Canyon section, Pelly River
8430 ± 60	TO-1279	This paper	Charcoal	Charcoal 90 cm above TO-951
9140 ± 540	AECV-484C	Ward (1989)	Wood	Minimum for deglaciation and establishment of upland vegetation, Pelly River
12,590 ± 120	TO-951	Ward (1989)	*Psidium sp.* shells	Minimum on deglaciation, Pelly River
MCCONNELL GLACIATION				
26,350 ± 280	TO-393	Jackson and Harrington (1991)	Bone (collagen)	Maximum on McConnell glaciation, mammal assemblage, Pelly Mountains
29,600 ± 300	TO-292	Matthews *et al.*, (1990a)	Seeds	Maximum on McConnell glaciation, xeric tundra, Stwart River
36,060 ± 2000	AECV-1422C	This paper	Allochthonous peat	Middle Wisconsinan site, spruce forest, Granite Canyon section, Pelly River
37,120 ± 350	TO-1278	This paper	Charcoal	Middle Wisconsinan site, spruce forest, Granite Canyon section, Pelly River
38,100 ± 1330	GSC-4554	Matthews *et al.*, (1990a)	Wood	Middle Wisconsinan site, spruce forest, MIV section, Stewart River
REID GLACIATION				
>41,000	GSC-4510	Ward (1989)	Allochthonous peat	Occurs below Reid deposits, Bradens Canyon section, Pelly River

Table 2-3: Radiocarbon ages mentioned in the text and their relationship to the McConnell and Reid glaciations.

volcanic deposits has also allowed absolute age determinations to be made (Table 2-2). Basalts underlying the older pre-Reid till yielded a whole rock K-Ar age of 1.60 ± 0.08 Ma, and the overlying Ft. Selkirk tephra yielded an isothermal plateau fission-track age of 1.48 ± 0.19 Ma (Westgate, 1989). Basalts erupted during the younger pre-Reid glaciation have yielded K/Ar ages of approximately 1.4 Ma. (Westgate, 1989). These absolute ages confirm an Early Pleistocene age.

The age of the Reid glaciation is uncertain. The subdued nature of Reid landforms when compared to McConnell landforms indicate an older age (Bostock, 1966; Hughes *et al.* 1969). It was considered to be Early Wisconsinan (Hughes *et al.* 1972) but subsequently was considered to be Illinoian because of an interglacial paleosol developed on deposits of Reid age (Hughes, 1987). Further corroboration was given by the fact that the Old Crow tephra occurs above the correlative Mirror Creek glaciation (Table 2-4) in the Snag-Klutlan area, southwestern Yukon (Rampton, 1971). Reported ages for the Old Crow tephra range from 86 to 220 ka (Table 2-2). TL age determinations of 86 ± 8 ka (Wintle and Westgate, 1986) and 109 ± 14 ka (Berger, 1987) have been determined. However, an isothermal fission track age of 140 ± 10 ka (Westgate, 1988; Westgate, 1989; Westgate *et al.*, 1990) suggests the TL dates are too young (Wintle, 1990). An age of 220 ka has also been suggested based on magnetic susceptibility (Beget and Hawkins, 1989) but the tephra's usual stratigraphic position immediately below or in association with deposits correlated to the last interglaciation (Hamilton and Brigham-Grette, 1991; Matthews *et al.*, 1990b) make this age unlikely. Sheep Creek tephra occurs above deposits of Reid age along the Stewart River at Ash Bend (Hughes *et al.* 1987), and U-series dates on bones associated with

General Chrono-stratigraphy	Oxygen Isotope Stage	Central Yukon	Southwestern Yukon, Snag-Klutlan area	Northern Yukon Basins	Bonnet Plume Basin	Brooks Range, Alaska
Late Wisconsinan Stage	2	McConnell glaciation	Macauley glaciation	Glaciolacustrine sediments from glacial blockage	Hungry Creek glaciation?	Itkillik II/ Walker Lake glaciations
Middle Wisconsinan Stage	3					
Early Wisconsinan Stage	5d-4			Alternating cold and warm conditions	Hungry Creek glaciation?	Itkillik IB/Chebanikia glaciations Old Crow tephra? Itkillik IA/Siruk Creek glaciations
Sangamonian Stage	5e	Koy-Yukon thermal event	Koy-Yukon thermal event	Koy-Yukon thermal event	Koy-Yukon thermal event	
Middle Pleistocene		Sheep Creek tephra Reid glaciation	Old Crow tephra Mirror Creek glaciation	Old Crow tephra		Sagavanirktok glaciation
Early Pleistocene		Younger pre-Reid Ft. Selkirk tephra Older pre-Reid				Anaktuvuk River glaciation

Table 2-4: Regional correlation with areas adjacent to the central Yukon. Modified from Jackson et al. (1991), Vincent (1989, 1992) and Hamilton (1986).

this tephra in Alaska implied an age of 80 ka (Hamilton and Bischoff, 1984). However, the Sheep Creek tephra has now been observed 2 to 3 m below the Old Crow tephra in the Fairbanks area which indicates an age >150 ka (J. Westgate, University of Toronto, personal communication, 1992). This suggests that the Reid glaciation is older than oxygen isotope stage 6 (stage 6). Because of this uncertainty in the age of the Reid glaciation it will be referred to as Middle Pleistocene.

The uncertainty of the age of the Reid Glaciation causes several problems in regards to correlation with the classical Midwestern stratigraphy. It appears that not only is there no known glacial activity during oxygen isotope stages 4 and 5 (Clague *et al.* 1992), but also no known glaciation during stage 6. This raises the fundamental question of whether correlation to the classical Midwestern stratigraphy for northern sites is valid. Other workers have also questioned the validity of this correlation (Kaufman *et al.*, 1991; Matthews *et al.*, 1990b). For this reason, the terms Sangamonian and Illinoian are not used in this report; however, the chronologic terms Late and Middle Wisconsinan are used since they can be assigned on the basis of radiocarbon dates.

The McConnell glaciation is known to be Late Wisconsinan in age on the basis of two finite radiocarbon ages under McConnell glacial deposits: 26,350±350 yr BP (TO-393) (Jackson and Harington, 1991), and 29,600±300 yr BP (TO-292) (Matthews *et al.*, 1990a). A Late Wisconsinan age is supported by the relatively fresh surface morphology of McConnell glacial deposits.

Interstadial and interglacial deposits have also been studied in Yukon. The record of pre-Reid interglaciations is represented by paleosols (Foscolos *et al.*, 1977; Rutter *et al.*, 1978; Tarnocai *et al.*, 1985; Smith *et al.*, 1986; Tarnocai and Schweger, 1991) but no nomenclature has been developed. The last interglaciation has been extensively studied in northern Yukon and

Alaska and has been assigned the informal term Koy-Yukon thermal event (Matthews *et al.*, 1990b). Because periods of maximum warmth in northern latitudes may not correspond to those in the south (Matthews *et al.*, 1990b), the term Koy-Yukon thermal event is used in preference to Sangamonian Interglaciation. Interstadial conditions from stage 3 are simply referred to as Middle Wisconsinan.

The Glenlyon map area lies very close to the westernmost limit of the McConnell glaciation, and many of its upland areas were nunataks (Figs. 2-1, 2-2). Deposits of older glaciations are exposed on these surfaces. These older surfaces have a much more subdued surface expression than surfaces covered by ice during the McConnell glaciation.

During the McConnell glaciation the Selwyn and Cassiar lobes advanced into the Glenlyon map area. The Selwyn Lobe (Campbell, 1967, p. 11) generally flowed west from its source in the Selwyn Mountains (Fig. 2-3) and inundated most of the map area (Fig. 2-7). The Cassiar Lobe (Wheeler, 1961, p.10) flowed north from the Cassiar Mountains and covered the southwestern portion of the map area (Fig. 2-7).

Regional Correlations

A chart presented in table 2-4 shows proposed correlation from the central Yukon to adjacent areas in Yukon, the Northwest Territories and Alaska. The correlation to southwestern Yukon is well established, based on similar preservation of surface features (Hughes *et al.*, 1969). The presence of Old Crow tephra on top of deposits correlated to the Reid glaciation helps to constrain its age. The fact that more extensive pre-Reid deposits do not occur in this area (Fig. 2-2) has been attributed to changing moisture distribution patterns caused by the uplift of the St. Elias Mountains since the Early

Figure 2-7: Ice flow directions, nunatak areas and contact between the Selwyn and Cassiar lobes during the maximum of the McConnell glaciation.

Pleistocene (Jackson *et al.*, 1991).

Correlation to the basins of northern Yukon is difficult because of the lack of glacial deposits. However, the northern Yukon provides a wealth of paleoenvironmental information, including information on the last interglaciation, the Koy-Yukon thermal event. Above deposits representing the Koy-Yukon thermal event, a record of alternating warm and cold periods is preserved. Glaciolacustrine sediments were deposited during the Late Wisconsinan when the Laurentide Ice Sheet blocked the drainage of the rivers in the area (Fig 2-1).

The Brooks Range preserves a record of two Early Wisconsinan glaciations, glaciations not represented in the central Yukon.. The Itkillik IB drift likely corresponds to stage 4 and the Itkillik IA likely corresponds to either stage 5b or 5d. The Old Crow tephra has been reported on Itkillik IA drift (Hamilton, 1986) suggesting a stage 6 age; however, recent fieldwork suggests that the tephra may have been soliflucted, so an Early Wisconsinan age remains a possibility (T. Hamilton, United States Geological Survey, personal communication, 1992). A lack of glacial activity in central Yukon during stages 4 and 5 is problematic since other northern sites, such as the western Canadian Arctic (Vincent, 1992), the north shore of Alaska (Flaxman Member of the Gubik Formation, Carter and Ager, 1989), and the eastern Canadian Arctic and northwest Greenland (Miller *et al.*, 1992) have a record of more extensive advances during stages 4/5 than during stage 2. As suggested by Vincent (1992), the Laurentide Hungry Creek glaciation in the Mackenzie Mountains could be stage 4/5 age. Further evidence is given by Schweger and Matthews (1992) when they assigned beds under the Hungry Creek glaciation to the last interglaciation, even though there is one finite date of 36,900±300 present. However, there is no distinctive flooding event

associated with this stage 4/5 glaciation in the northern Yukon Basins as there is for the stage 2 event (Matthews *et al.*, 1990b; Schweger and Matthews, 1992). The reason for the dichotomy between the glacial record of the central Yukon and the areas adjacent has not been determined.

SURFICIAL GEOLOGY

Classification of Landforms and Surficial Materials

The surficial geology of the Glenlyon map area has been mapped using a simplified version of the British Columbia Terrain Classification System (Resource Analysis Unit, 1976). For the purposes of this report, geological materials have been divided into two major groups: (1) consolidated material (bedrock); and (2) unconsolidated materials (Quaternary sediments). Surficial materials have been sub-divided according to their genesis (e.g., glaciofluvial, fluvial), surface expression (e.g. blanket, veneer, fan), and in some cases stratigraphic age, texture and modifying process.

Genesis

E - Eolian. Eolian sediments are transported and deposited by wind. In the map area eolian deposits consist of loess, dune sand and tephra. They can form a thin veneer or blanket, or distinctive dunes (Plate 2-3). Deposits generally consist of fine sand and silt and are well sorted. The sediments range from weakly stratified to massive in blankets and veneers, to stratified in dunes.

Many of the eolian blankets and veneers are composed of loess (wind blown silt) which was deposited at the end of the last glaciation and during early postglacial time as vegetation became established (Tarnocai *et al.*,

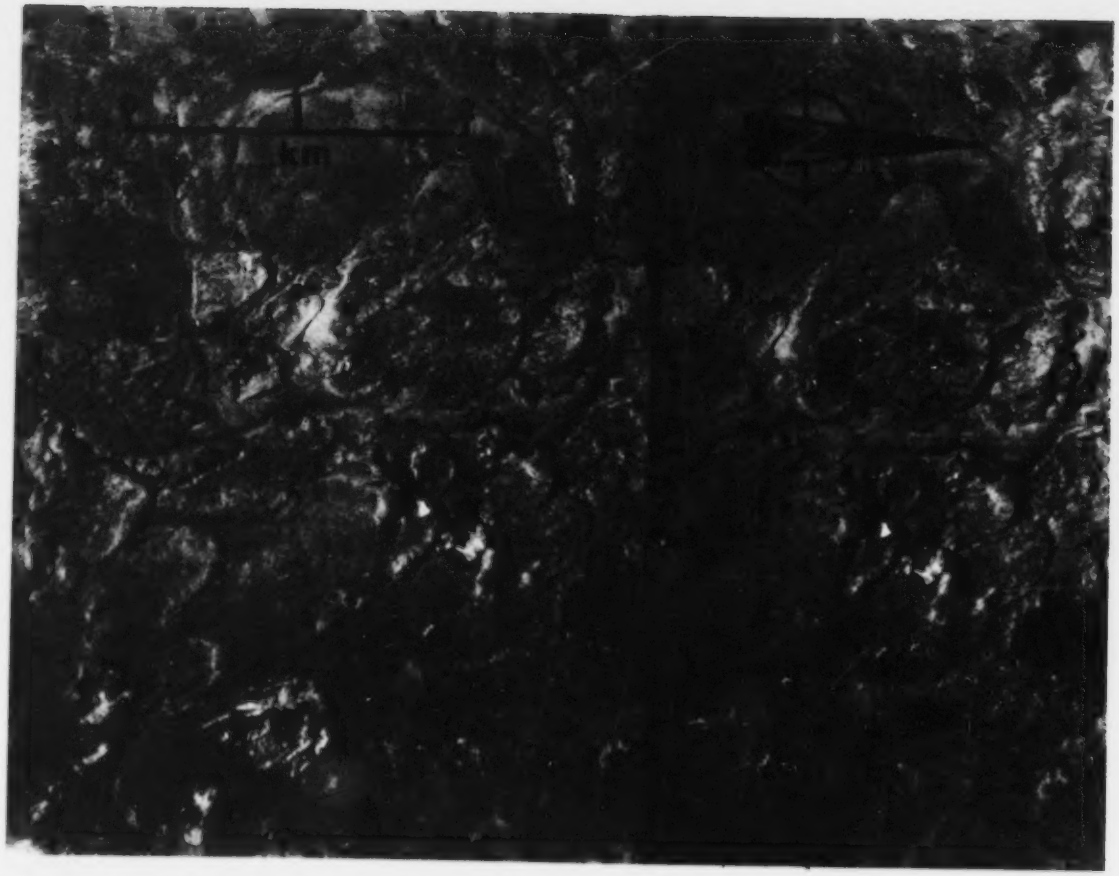


Plate 2-3: Parabolic dunes near the southwest margin of the map area (Map 1789A) (National Air Photo Library A12174-24 and 25)

1985). Eolian veneers, which are generally less than 50 cm, are widespread in low-lying and moderately sloping areas but are too thin to map.

White River tephra, deposited ca. 1250 BP during the cataclysmic eruption of Mount Bana near the Alaska-Yukon boundary (Lerbekmo *et al.*, 1975), covers much of southern and central Yukon and occurs throughout the southern three quarters of the map area. The tephra is locally overlain by eolian sediments, indicating that eolian activity is continuing.

Parabolic dunes (Plate 2-3) most likely formed at the end of the last glaciation (Campbell, 1967), while "cliff-top deposits" (David, 1972) which resemble dunes have accumulated at the tops of river bluffs from winds eroding material from below. Cliff-top deposits are too small to map, but they are indicated on some measured sections.

O - Organic. Organic deposits are accumulations of dead vegetation in areas of poor drainage (perched water table) or where the water table intersects the ground surface. This water is essentially stagnant and becomes anoxic, thus, the dead vegetation does not fully decompose. Organic deposits are comprised of peat and gyttja, in some cases with occasional layers and lenses of mineral material. They accumulate in bogs, fens, and lakes, which occur on floodplains, valleys, and shallow depressions. In addition, blanket bogs are common on poorly drained slopes underlain by permafrost. Organic deposits free of permafrost are commonly hummocky, containing tussocks with <1 m of relief. Organic deposits which are less than 1 m thick are simply indicated with a symbol.

Permafrost is commonly present in surface organic deposits. The growth of segregated ice bodies can result in low hills or mounds, commonly with relief >1 m, termed palsas and larger hills termed open system pingos (cf. Hughes, 1969).

A - Alluvial (Fluvial). Alluvial sediments are deposited by rivers and streams under non-glacial conditions. The characteristics of the deposits are related to the specific depositional environment. Gravels deposited in channels and on bars are generally moderately sorted, well stratified (locally with cross stratification), well imbricated, and contain well to moderately rounded clasts. Conversely, gravels deposited in alluvial fans are moderately to poorly sorted, poorly to weakly stratified, poorly to moderately imbricated, and contain angular to moderately rounded clasts. As well, alluvial fans can contain significant amounts of diamicton, deposited by debris flows and avalanches. Sands and silts deposited in overbank environments are generally well stratified and can contain ripple and ripple-drift stratification; this stratification may be locally disrupted by ice push during spring breakup.

Alluvial deposits also have a range of topographic expression. Streams with steep gradients deposit mainly coarse gravels with little overbank material, forming an irregular topography of small terraces and fans. Alluvial fans form where steep, high energy streams enter valleys with lower gradients. Deposits of low-gradient rivers and streams underlie planar to slightly undulatory, gently dipping surfaces, either terraces or plains. They consist of gravel and sand, overlain by silty overbank deposits.

C - Colluvial. Colluvium consists of material that has been transported and deposited by subaerial gravitational processes. These processes range from high-velocity rock falls, to low-velocity soil creep and solifluction (downslope creep caused by seasonal thaw and saturation)(Fig. 2-8).

Colluvial deposits are commonly poorly sorted and consist of diamicton or rubble, deposited as veneers, blankets, fans, aprons or landslides (see **Landforms**). The nature of the deposit depends on the source material and

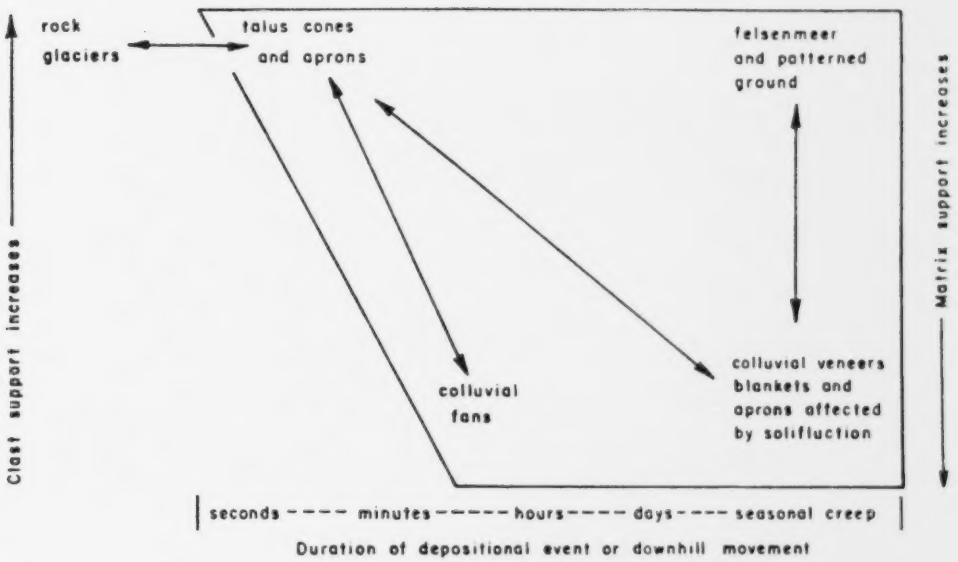


Figure 2-8: Genetic classification of colluvial landforms based on the duration of the formative event or ongoing gravitational transport. From Jackson (1987, Fig. 9).

the style of transport. Blocky talus cones and aprons with little fine grained sediment form in steep mountainous areas with coarse grained bedrock. Blockfields and sorted stone polygons form on gentle slopes in alpine areas with coarse grained bedrock. Steeper slopes with finer grained bedrock and/or surficial materials commonly are mantled with soliflucted diamicton forming a complex of overlapping lobes. Colluvial aprons and cones form in alpine areas through snow avalanching, rock falls and debris flows.

M - Morainal. Morainal deposits consist dominantly of diamicton deposited either directly by glacier ice or in close proximity to glacier ice. In the past, morainal deposits have been commonly mapped as till. "Till" is dominantly unsorted and unstratified sediment deposited directly by a glacier without subsequent reworking. It consisting of a heterogeneous mixture of clay, silt, sand, gravel and boulders ranging widely in size and shape (Bates and Jackson, 1980, p.653). Studies of the marginal areas of active glaciers, however, indicate that much of the material deposited directly from ice is subsequently remobilized and no longer represents a true "till" (Lawson, 1979, 1981). The term "glacial diamicton" is used to describe these sediments and it pertains to all diamictons formed in a proximal glacial environment.

Glacial diamicton ranges from massive (Plate 2-4A) to stratified (Plate 2-4B), and lenses of sorted material may also occur. Stratification, where present, is marked by sorted layers or by slight changes in colour, grain size of matrix, or concentration of clasts >2 mm.

The texture of glacial diamicton is highly variable (Fig. 2-9, Appendix 1). Although, in many areas there is a relationship between glacial diamicton texture and bedrock composition (Haldorsen, 1977, 1978), this is not the case in the map area. This likely reflects the highly complex spatial distribution of

A

B

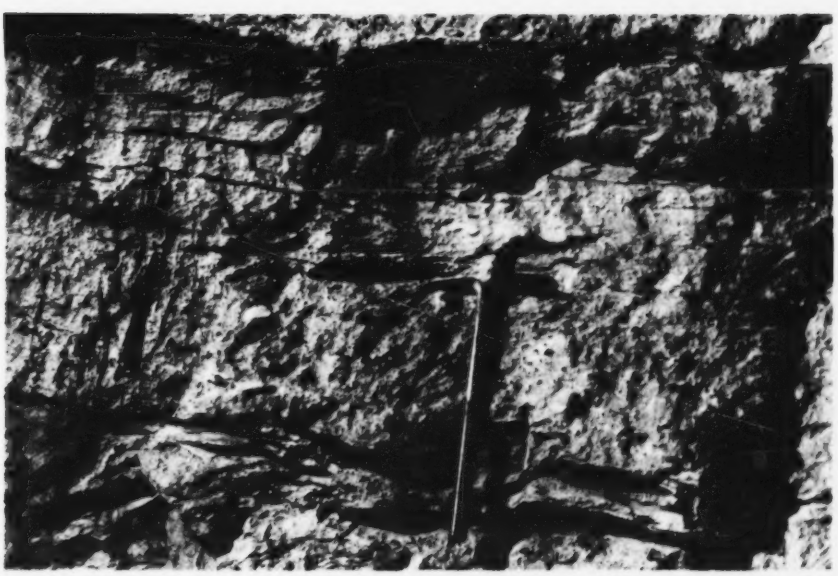


Plate 2-4: A-Massive glacial diamicton at the base of Section 17 (Map 1787A). The head of ice axe is 30 cm long. B-Stratified glacial diamicton at Section 32 (Map 1786A). Pick is 65 cm long.

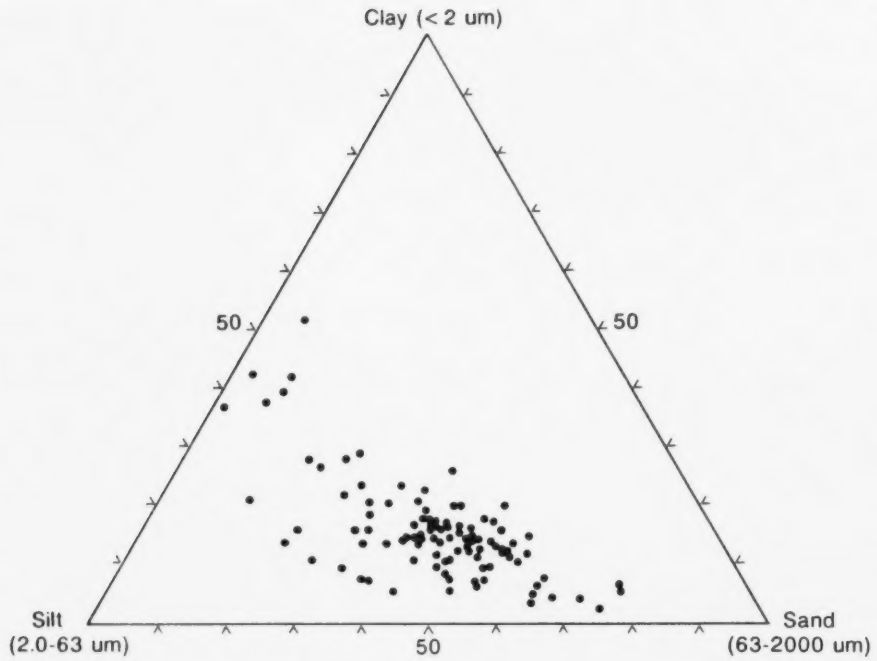


Figure 2-9 Particle size of glacial diamicton samples. Data are presented in Appendix 1.

different bedrock types in the map area (Fig. 2-6). Depositional processes also influence matrix grain size: abrasion during lodgement produces abundant silt, whereas, meltwater can remove fine grained material during meltout (Haldorsen, 1981, 1983a, 1983b). In addition, diamicton deposited by subaqueous debris flows may include previously deposited fine grained material, resulting in a finer grained matrix.

Even at the same site, wide ranges in grain size were observed. The thick glacial diamicton sequence at sample site 21 (Section 20, Map 1787A) was sampled extensively for particle size analysis. These samples range in grain size from 55% sand, 33% silt, and 12% clay to 6% sand, 42% silt, and 52% clay (Appendix 1). This range likely reflects depositional controls.

The concentration of clasts >2 mm in glacial diamictons ranges from 10% to 40%, and averages 25% to 30%. Clasts >2 mmrange from pebbles to boulders, and their shape ranges from angular to rounded, with most being subrounded. Many of these clasts are striated and faceted.

The morphology of morainal deposits is variable. They commonly form blankets and veneers, thus their morphology is usually controlled by that of the underlying deposit or bedrock. Some morainal deposits, however, form flutings, drumlins, moraines and thick units in major valleys.

G - Glaciofluvial. Glaciofluvial sediments are transported by meltwater from glaciers and deposited in ice-contact, proglacial and paraglacial environments. Deposits include outwash plains, terraces, and fans, deltas, and ice stagnation complexes.

Glaciofluvial deposits generally comprise gravel and sand, although minor amounts of silt and diamicton are common and have a variable morphology. The gravel is generally clast supported, poorly to moderately

sorted, massive to well stratified, and commonly has weak to strong imbrication. The amount of interstratified sand, silt and diamicton is variable. Rapid facies changes are common where deposition occurred in an ice-proximal position. The melting of buried or marginal ice has produced deposits that are folded and faulted. These deposits underlie irregular, hummocky and pitted terrain and also form ridged landforms such as eskers and crevasse fillings. Where deposition occurred in more distal environments with respect to the ice, deposits show fewer facies changes and are less disturbed. They form planar to gently rolling terrain; some of these landforms are terraced or have kettles.

In many cases outwash is difficult to distinguish from alluvium. Terrace deposits are considered to be glaciofluvial in origin if formed by rivers with a more braided form than present. Braided river forms result from high sediment loads derived, in part, by the erosion of glacial sediment on recently deglaciated slopes and as rivers cut down through thick deglacial valley fills. The paraglacial effect has been introduced by Church and Ryder (1972, p. 3059) to define nonglacial processes, such as this increased sedimentation, that are directly conditioned by glaciation. These paraglacial deposits are mapped as glaciofluvial because the sedimentation more closely approaches that of glaciofluvial than alluvial conditions. However, the distinction is rather arbitrary, terraces that are above approximately 25 m above the present river level are mapped as glaciofluvial while those below this are mapped as alluvial.

L - Glaciolacustrine. Glaciolacustrine sediments are deposited in lakes dammed by glaciers or stagnant ice. Sources of sediment include meltwater streams, stagnant ice, the glacier margin, icebergs, and deposits along the

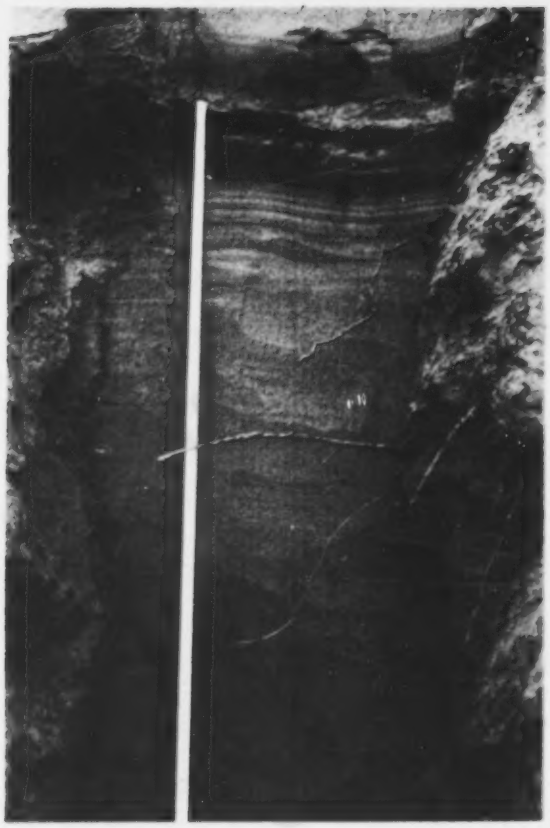
lake margin. Deposition is dominated by suspension and tractional currents, sediment gravity flows and iceberg rafting. Sedimentation rates are commonly high, resulting in soft sediment deformation features, such as load casts, folds and dewatering structures, such as dish and pillar structures.

Sediment texture and bedding are determined largely by the location of the major sediment source(s). In those parts of the lake distal from meltwater streams and the ice margin deposition is mainly from suspension and distal underflow, and deposits consist of well bedded to laminated sand, silt and clay (Plate 2-5A); although, coarser deposits, gravel and diamicton, from debris flows or iceberg rafting may be common locally. In more proximal areas, sediment gravity flow processes are important and the deposits are coarser, consisting mainly of sand, gravel and diamicton. Where sediments were deposited on top of, or adjacent to, stagnant ice, disruption due to slumping, folding, and faulting is common (Plate 2-5B).

Thickness, depositional history and presence of premafrost have a control on the morphology of glaciolacustrine deposits. Thick deposits of glaciolacustrine material have planar to gently rolling surfaces or ridged, hummocked, or pitted surfaces caused by the melting of buried ice. Thinner deposits drape and conform to underlying topography. Fine grained glaciolacustrine deposits commonly contain segregated ice lenses which can form palsas and pingos. Permafrost can degrade producing thermokarst lakes and retrogressive thaw slides (Plate 2-6).

R - Bedrock. Areas mapped as bedrock consist of exposed rock or rock with only a patchy covering of morainal deposits or colluvium. These areas may include such periglacial landforms as blockfields, sorted stone polygons, and solifluction lobes that are too small to indicate at the scale of mapping.

A



B

Plate 2-5: A-Well stratified glaciolacustrine sediments from Section 28, Map 1786A. Visible portion of tape is 50 cm. B-Folded glaciolacustrine sediment at Section 5 (Map 1789A).

Plate 2-6: Retrogressive thaw slide in fine-grained glaciolacustrine sediments, Section 30 (Map 1786A). The section is 32 m high.

Landforms

Landforms are geomorphic features that are recognizable and definable on the basis of slope, shape, and spatial distribution. Landforms in this study can be divided into two types: 1) large features that can be depicted as map units; and 2) small features that are indicated with a symbol and occur within or along the margin of map units.

Large Landforms - Large scale landforms are used to subdivide the genetic categories on the map sheets (Maps 1786A, 1787A, 1788A, 1789A). The descriptions below are modified after Clague (1984).

a - Apron. An apron is a constructional landform which has a planar to semi-planar upper surface with a relatively steep gradient, generally in excess of 20-25°. Aprons form by colluvial and fluvial processes at the break in slope where steep valley sides meet valley bottoms (Fig. 2-10A). Aprons are thickest (commonly >10m) at midslope, and thin upslope and downslope.

b - Blanket. A blanket is a continuous or nearly continuous mantle of sediment that drapes the underlying material (Fig. 2-10B). Blankets generally are >1 m thick but locally they can be thinner.

d - Delta. A delta is a constructional landform that forms where a stream or river enters a standing body of water. It has a triangular plan shape with a flat to gently sloping upper surface, terminated by a steeper scarp.

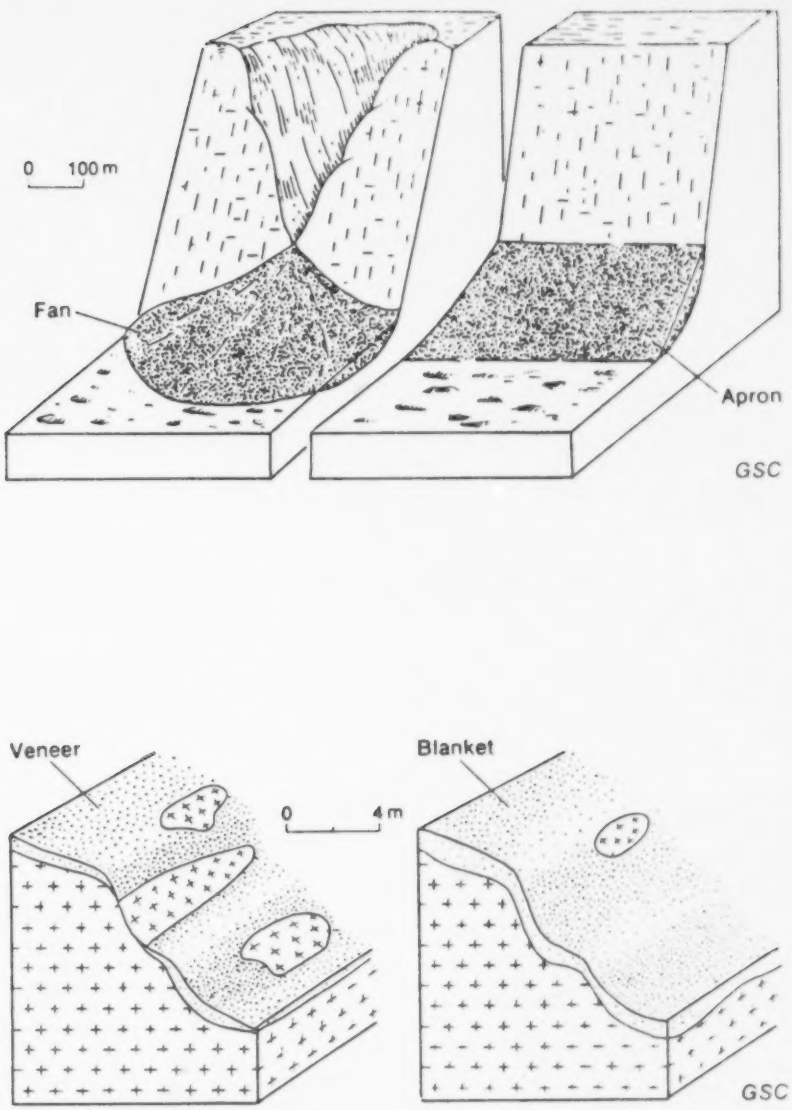


Figure 2-10: A-Representative landforms: fan and apron. From Clague (1984). B-Representative landforms: veneer and blanket. From Clague (1984).

f - Fan. A fan is a constructional landform with an inverted conical shape with slopes generally less than 15° but locally are as high as 30° (Fig. 2-10A). They form where high gradient streams become unconfined, commonly at the mouths of tributary valleys.

p - Plain. A plain is a flat or gently sloping surface with <1 m of relief. It represents an accumulation of fluvial, glaciofluvial or glaciolacustrine sediment.

t - Terrace. A terrace is one or more, flat or gently sloping surfaces truncated by steeper slopes. Terraces generally indicate erosion, but they can also be constructional (e.g. kame terraces).

u - Undivided. Undivided refers to two or more landform types that cannot be differentiated at the 1:100,000 scale of mapping.

v - Veneer. A veneer is a thin (<1 m), typically discontinuous mantle of surficial material (Fig. 2-10B). It conforms to the underlying bedrock or surficial unit, having little if any surficial expression of its own.

x - Complex. A complex has highly variable relief, and consists of several of the following surface expressions: hummocks; ridges; pits; plains; terraces; and channels. It results from deposition in and around stagnant ice which subsequently melts.

Small Landforms

Arête. An arête is a narrow, sharp ridge formed by glacial erosion and frost action. They generally occur in areas of bedrock in alpine regions and can be associated with bouldery colluvial aprons.

Cirque. A cirque is a deep, steep walled, half-bowl or armchair-shaped hollow formed by glacial erosion. They occur in bedrock in alpine areas, usually at the heads of valleys. Cirques in the map area were formed by alpine glaciers which are no longer present, although many contain rock glaciers.

Cryoplanation terrace. Cryoplanation terraces are gently sloping, erosional benches or surfaces on summits or hillsides. They are covered with 1 or 2 m of bedrock rubble and blocks with some interstitial finer material (Washburn, 1979; Hughes, 1990). Large, well developed terraces are generally considered to form over tens of thousands of years by colluvial and permafrost processes with gelifluction being the most important (Washburn, 1979). Their distribution and development in Yukon is discussed by Hughes (1990, p.14-16). Within the map area, they are only found in the alpine zone above the Reid ice limit (Map 1786A).

Esker. Eskers are long, narrow, steep-sided, usually sinuous ridges composed of sand and gravel. They are formed by water flowing in a supraglacial, englacial and subglacial environment and are often oriented approximately perpendicular to the ice front. Eskers are associated with glaciofluvial or morainal units.

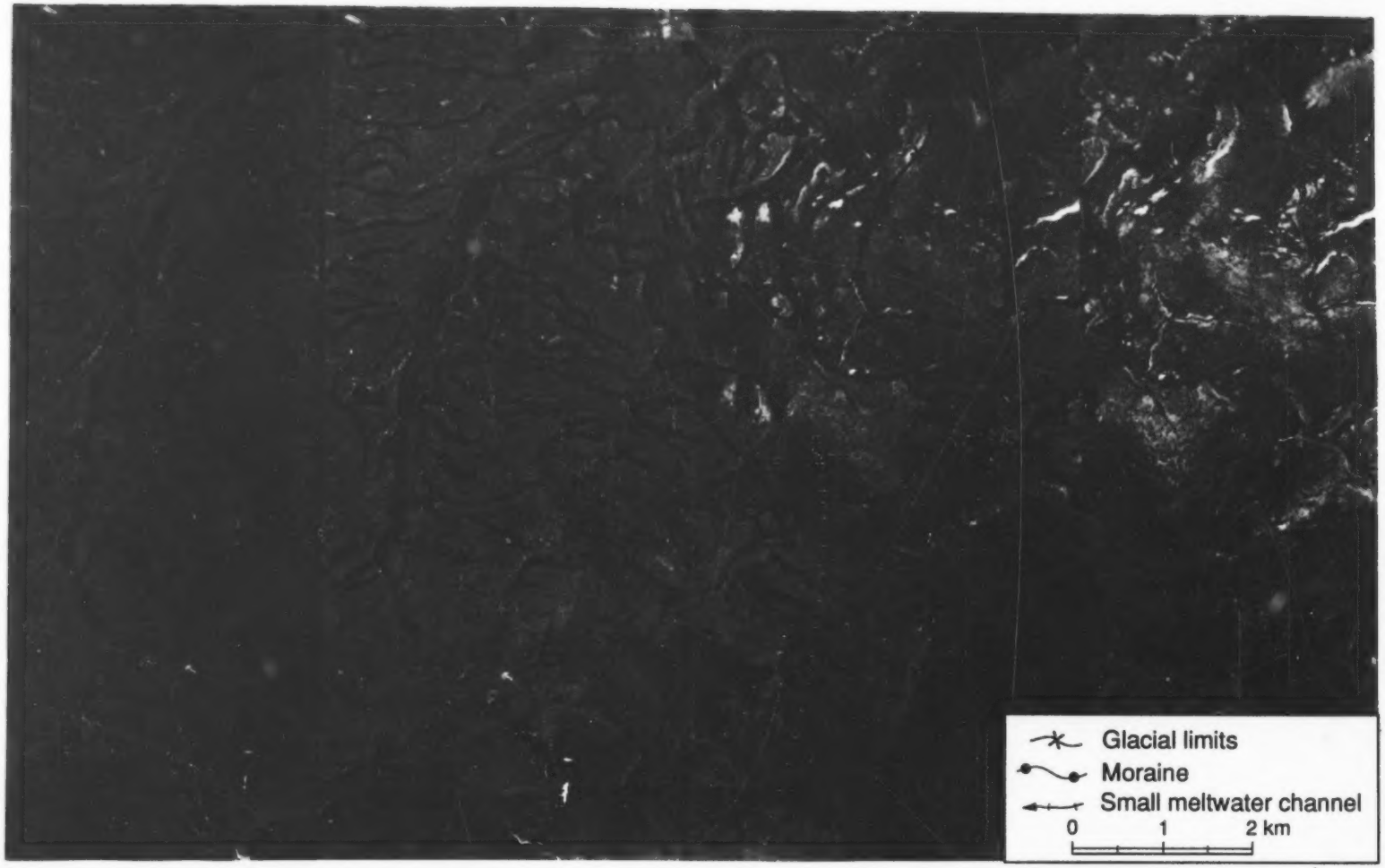
Glacial limits. Glacial limits delineate the maximum limits of glaciations and are marked by a wide variety of landforms. The limits may be inconspicuous, indicated by slight changes in topography and weathering, or well defined, marked by moraines and meltwater channels (Plate 2-7). Glacial limits commonly correspond to map unit boundaries (Maps 1786A, 1787A, 1788A, and 1789A)

Landslide. Landslides are mass-movement landforms and processes. The deposits are colluvial and their character is determined primarily by the material that has failed.

Landslides involving bedrock are most common in Cretaceous and Tertiary volcanic rocks. The largest landslide in the study area is in Cretaceous volcanic rocks of the Carmacks Group (Plate 2-8).

Retrogressive thaw flow slides, also called bimodal slides, or thaw slumps, (McRoberts and Morgenstern, 1974; Washburn, 1979; Burn, 1987) commonly occur in fine-grained, ice-rich diamictons or glaciolacustrine deposits (Plates 2-6, 2-9). They are a form of thermokarst (Washburn, 1979). Failure is caused by the exposure of ice rich sediments, often due to fluvial erosion, and also by forest fires or human activities such as road building. Progressive melting during the summer causes liquefaction and flow from a steep headwall (McRoberts and Morgenstern, 1974). Failure is generally slow, however if enough water saturated sediment accumulates, a debris flow could be generated. Failure usually continues until either the ice-rich ground is exhausted or an insulating material, usually a thick vegetative mat, covers the thaw face (Burn, 1987). Retrogressive thaw slides are very common in fine-grained glaciolacustrine sediments along the Pelly and Macmillan rivers.

Plate 2-7: Area near Lyon Creek showing glacial limits, moraines, small meltwater channels, glaciofluvial deltas (Gd), and glaciofluvial complexes (Gx). Drury lake is immediately south of the stereotriplet. National Air Photo Library A20693 - 128, 129 and 130.


Glacial limits
Moraine
Small meltwater channel
0
1
2 km

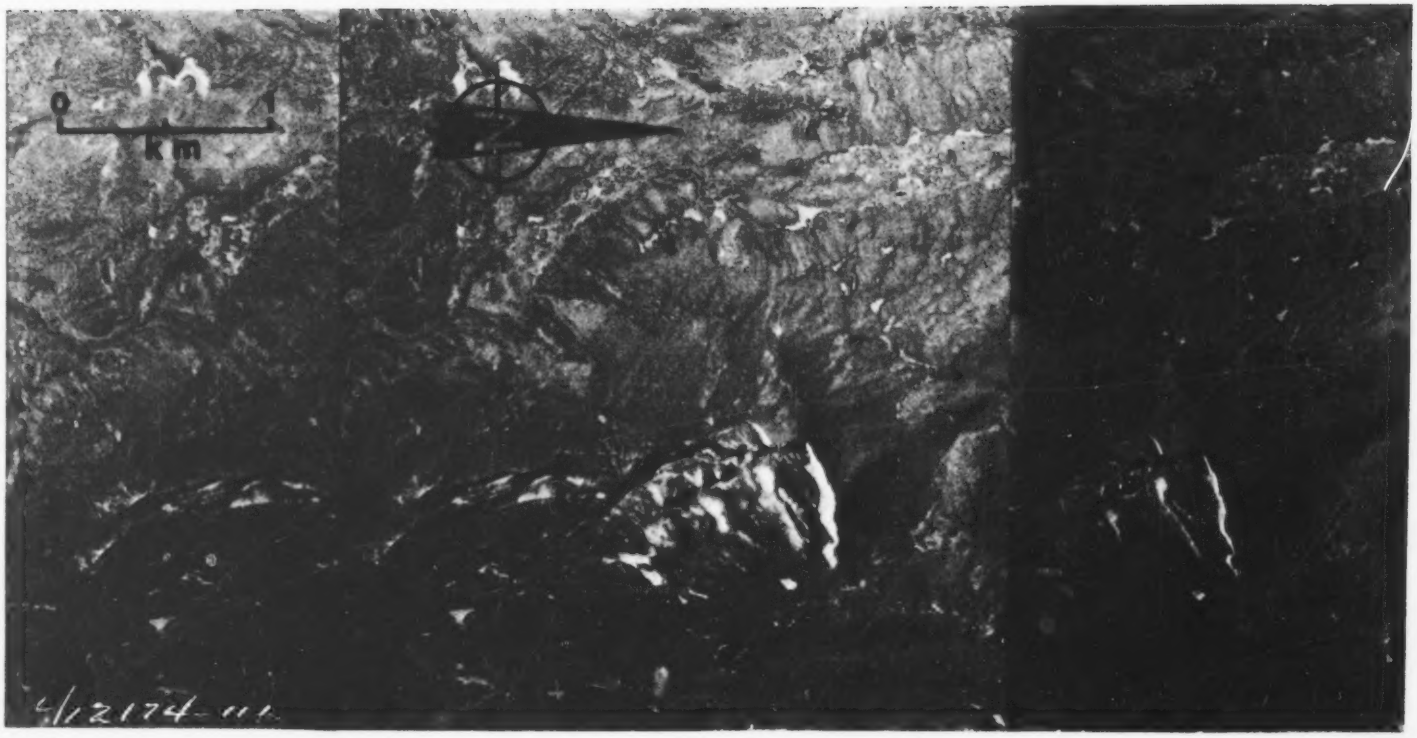


Plate 2-8: Landslide in Carmacks Group volcanic rocks (Map 1788A). National Air Photo Library A12174 - 109, 110 and 111.

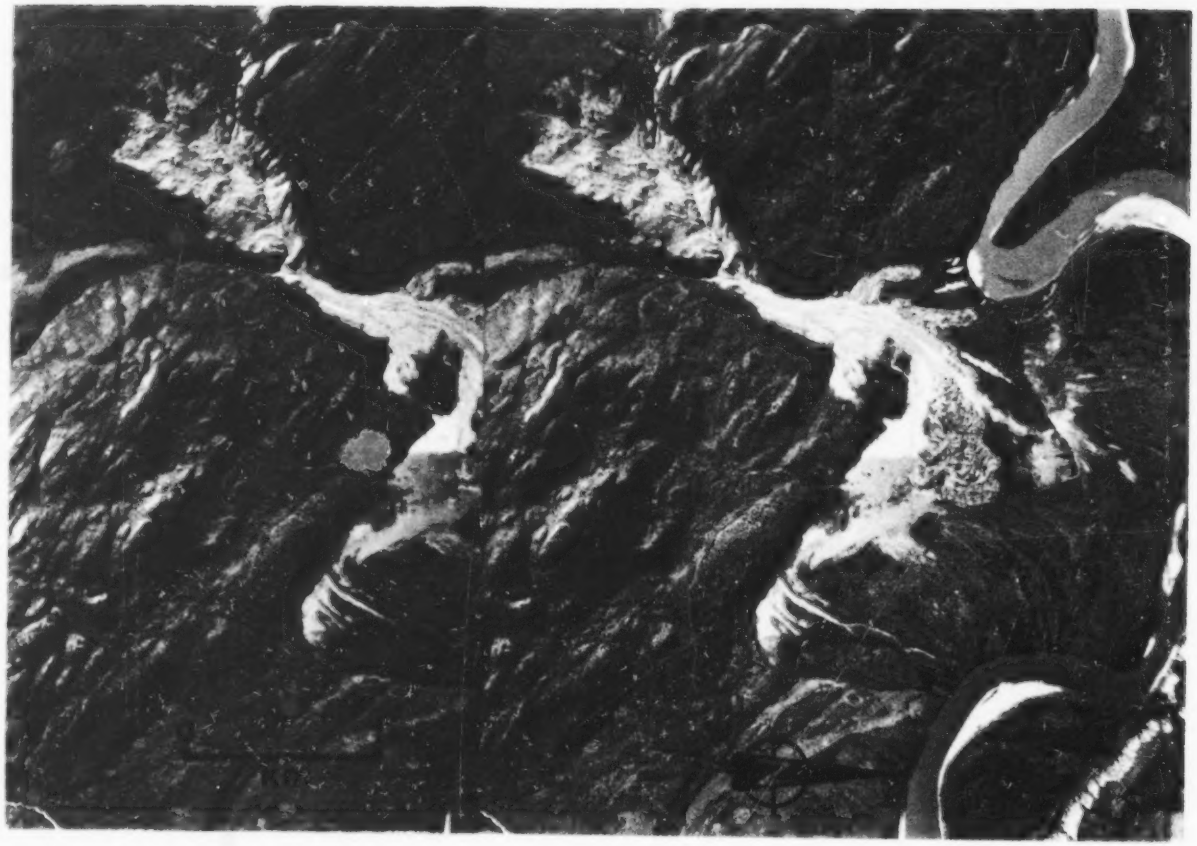


Plate 2-9: Landslide in fine-grained morainal material along the eastern margin of the map area (Map 1787A). National Air Photo Library A12182 - 127 and 128.

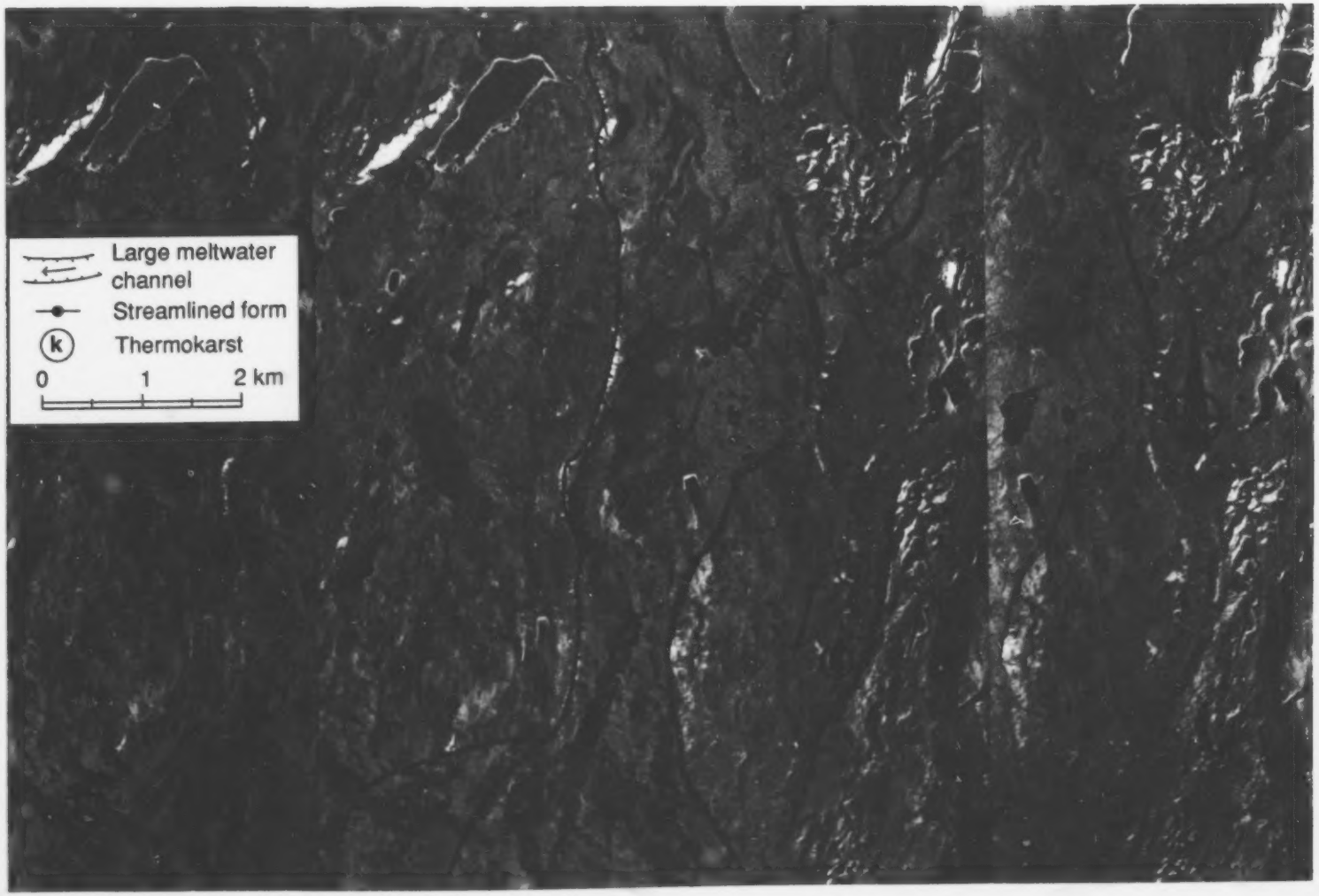
Meltwater channel. Meltwater channels are cut in either bedrock or surficial sediments by glacial meltwater in an ice-contact or proglacial environment. Small and large channels have been differentiated. Small meltwater channels are generally <100-200 m wide and range from small notches cut in bedrock (Plate 2-7), representing ice-marginal positions, to more extensive channel systems (Plate 2-7). Large channels are up to 3 km wide and represent major discharge paths from ice or glacial lakes (Plate 2-10). They can occur within any map unit and can delineate unit boundaries. Both small and large channels may have been ice walled.

Moraine. Moraines are elongate ridges with rounded or steep sides deposited at the margin of a glacier (Plate 2-7). They usually consist of diamicton, but where the glacier terminated in a lake, they may consist of stratified sand and gravel.

Pingo. Pingos are large conical hills formed by the growth of a large body of segregated ice, insulated by fine grained or organic deposits. If the insulating mat is disrupted by continued ice growth or by fire, degradation can occur, producing a collapsed centre. The pingos in the study area are open-system pingos, the most common form of pingo in Yukon (Hughes, 1969), which are fed by groundwater flow down hillsides and have a relatively long growth cycle, lasting many years (Washburn, 1979, p. 183).

Rock glacier. Rock glaciers are spoon- or tongue-shaped masses of poorly sorted rubble and blocks which deform and flow downhill under the influence of gravity. They are either cored by ice or have an ice matrix. They have steep fronts when active and many have transverse ridges. Rock glaciers are

Plate 2-10: Area adjacent to Ess Lake (Map 1788A) showing large meltwater channels, thermokarst, moraines and streamlined forms. National Air Photo Library A20059 - 97, 98 and 99


Large meltwater channel
Streamlined form
k
Thermokarst
0
1
2 km

commonly found in cirques or at the base of steep slopes where avalanche and rockfall debris contribute to their formation. They commonly are associated with bouldery colluvial aprons.

Streamlined glacial bedforms. Streamlined glacial bedforms include flutes (parallel ridges with constant width and height) and drumlins (smooth, low, oval hills with the morphology of inverted spoons or whalebacks) (Plates 2-2, 2-10). Although the origin of drumlins is controversial (Shaw and Kvill, 1984; Shaw and Gilbert, 1990), the long axes of these and other streamlined forms are assumed to be parallel to the direction of glacial movement. These features are developed in both bedrock (rock drumlins or drumlinoids) and surficial material.

Terrace. Terraces are step-like erosive features separated by scarps. Large terraces are used to define map units; however, this small landform is used to indicate different stages of formation within a map unit. For example, a map unit such as an alluvial terrace (At) may contain two levels of terraces formed at different times; these are differentiated with the terrace landform symbol.

Thermokarst Lakes. Thermokarst refers to topographic depressions formed by the melting of ground ice (Washburn, 1979). Thermokarst lakes are circular or elliptical in shape and often have scalloped edges (Plate 2-10). Climatic warming or disturbance of the insulating vegetative mat causes thickening of the active layer, resulting in ground subsidence and ponding of water (Burn, 1987). Thermokarst lakes indicate the presence of permafrost, and are common in fine grained glaciolacustrine and alluvial deposits, as well as in organic deposits.

Tor. Tors are exposures of rock that stand up from the surrounding slopes (Plate 2-11) and form by differential weathering and removal of the debris by mass movement (Washburn, 1979, p. 78). They occur mainly in alpine areas and, as has been noted in other areas in Yukon (Hughes, 1990), almost always above the Reid limit.

Texture

Texture refers to the size, shape and arrangement of the constituent elements in a sedimentary deposit (Bates and Jackson, 1980). Common textural terms used in this report include the following (modified from Clague, 1984, Bates and Jackson, 1980):

matrix:	finer grained material between the larger grains
clast:	an individual constituent, grain or fragment of s sedimentary deposit, produced by mechanical weathering
matrix-supported:	a sedimentary texture where the larger particles are not in contact but are separated by finer particles
clast-supported:	a sedimentary texture where the larger particles are in contact
boulders:	rounded particles >256 mm
blocks:	angular particles >256 mm
cobbles:	rounded particles 64-256 mm
pebbles:	rounded particles 2-64 mm
rubble:	angular particles 2-256 mm
sand:	particles 0.062-2 mm
silt:	particles 0.002-62 mm
clay:	particles <0.002 mm

Plate 2-11: Tors on Glenlyon Peak, Glenlyon Range.

gravel:	accumulation of rounded particles which are generally larger than sand; can be clast- or matrix-supported with, the matrix generally being sand
diamicton:	a matrix-supported mixture of clay, silt, sand, pebbles, cobbles, and in some cases boulders
peat:	deposit of fibrous, partly decayed fragments of vascular plants
gyttja:	fine-grained organic matter deposited or precipitated in a lake

Textures of map units are summarized in ***Description of Map Units***.

Geomorphic Processes

There are three important geomorphic processes in the study area: avalanching, mass movement (landslides), and permafrost (pingos, retrogressive thaw slides and thermokarst lakes). Each is indicated either by a letter modifier added to the unit designator, or by a symbol.

Avalanching is the rapid downslope movement of snow. Avalanches can incorporate abundant bedrock blocks and surficial material, and deposit them at the base of the slope as bouldery colluvial fans or colluvial aprons. Avalanching is indicated on the maps by the letter symbol A being added to the bedrock map unit (R).

Individual landslides, pingos, retrogressive thaw slides and thermokarst lakes are indicated by symbols on the maps and are described in more detail in the section on **Landforms**.

Age of Glacial Events

Deposits of glaciations older than the McConnell glaciation are indicated by a superscript after the genesis indicator. Reid deposits are denoted by the superscript R (e.g. $M^{R}v$) and pre-Reid deposits with the superscript PR (e.g. $M^{PR}v$).

Description of Map Units

The map units were delineated mainly on the basis of genesis and large landforms. Some further subdivision was made according to texture, modifying process and age of glacial event. Map units are grouped generally in order of decreasing age.

Pre-Quaternary

Bedrock (R, R-A)

Bedrock is exposed in alpine areas, on steep slopes where surficial materials have been removed by colluvial processes and in stream cut channels. Most bedrock exposures occur in the Glenlyon, Little Salmon, Big Salmon, Macmillan, and Kalzas ranges. Areas mapped as bedrock also include variable amounts of surficial sediments, mainly glacial diamicton and colluvium, that are either too small or too patchy to be shown at the scale of mapping. Areas of bedrock above the limit of the McConnell glaciation contain a higher percentage of colluvium, felsenmeer and soliflucted rubble, than those below this limit.

Pre-Illinoinan - pre-Reid

Pre-Reid glacial diamicton veneers ($M^{PR}v$)

Glacial diamicton veneers of pre-Reid glaciations are similar to those of the McConnell glaciation (see **Late Wisconsinan - McConnell**) However,

they contain larger amounts of colluvium and have very subdued landforms because there has been more time for colluvial processes to modify them. Detailed soil studies to the north and northeast of the map area indicate that the pre-Reid deposits can contain a paleosol (Wounded Moose paleosol) that, although truncated, is much more developed than the present soil on comparable materials of McConnell age (Tarnocai *et al.*, 1985; Smith *et al.*, 1986). Deposits of pre-Reid glaciations occur in the western part of the map area (Maps 1786A and 1788A).

Illinoian - Reid

Reid glacial diamicton veneers (M^Rv)

Glacial diamicton veneers of the Reid glaciation are similar to those of the McConnell glaciation (see **Late Wisconsinan - McConnell**) but contain larger amounts of colluvial material and have more subdued landforms. They can contain a paleosol (Diversion Creek paleosol) that is intermediate in development between those developed on McConnell and pre-Reid deposits (Tarnocai *et al.*, 1985; Smith *et al.*, 1986). These deposits occur above the limit of the McConnell glaciation, mainly in the western part of the map area (Maps 1786A and 1788A); there are also small occurrences in the Glenlyon Range (Maps 1787A and 1789A).

Reid glaciofluvial delta G^Rd

Glaciofluvial deltas of the Reid glaciation are similar to those of the McConnell glaciation. However, as mentioned above, they commonly show evidence of greater colluvial reworking and deeper pedogenesis than similar McConnell deposits. They occur mainly in the western part of the map area (Maps 1786A and 1788A).

Late Wisconsinan - McConnell

Glacial diamicton blankets and glacial diamicton veneers (Mb, Mv)

Glacial diamicton blankets and veneers are >1 m and <1 m thick, respectively, and occur throughout the map area. These units locally include thicker deposits associated with moraines. Glacial diamicton blankets and veneers usually drape bedrock and display a streamlined to gently undulatory surface form. In some of the larger valleys they cover older sediments. Glacial diamicton blankets occur most commonly in areas of low relief in the western part of the map area. Throughout the rest of the map area, with its higher relief and steeper slopes, glacial diamicton veneers are more common. Areas mapped as glacial diamicton veneer often contain small areas of glacial diamicton blanket, and vice versa. Veneers are often reworked into colluvial veneers or aprons on slopes >~20°. Both blankets and veneers may contain patches and areas of bedrock, colluvium, and in places glaciolacustrine and fluvial sediments too small or thin to be indicated at the scale of mapping.

Glaciofluvial plain and fan (Gp)

Glaciofluvial plain sediments are >2 m thick and were deposited as outwash in front of retreating ice or when glacial lakes drained and braided streams deposited gravels (Plate 2-2). Glaciofluvial plains occur in many of the main valleys and within large meltwater channels (Plate 2-10). The sediments consist dominantly of moderately stratified, approximately horizontal gravel, often capped by thin sand and silt.

Glaciofluvial fan sediments, which are rare in the map area, are >5 m thick. They formed when water from a confined meltwater stream entered a large valley. They consist of interstratified gravel and sand with minor diamicton.

Glaciofluvial terrace (Gt)

Sediments of glaciofluvial terraces are generally <2 m thick and were deposited as glacial streams incised thick valley fill sequences. Glaciofluvial terraces are common along the main valleys and in large meltwater channels. The associated sediments are moderately stratified gravel capped by sand.

Glaciofluvial deltas (Gd)

Sediments of glaciofluvial deltas, generally >5 m thick, are common throughout the map area because a large number of glacial lakes existed during deglaciation. They consist of dipping, well stratified sand and gravel capped by horizontally bedded gravel. When deposited in close association with ice, these sediments typically are deformed, usually by faulting and slumping. They are differentiated from glaciofluvial terraces on the basis of their geomorphic expression, and in exposed sections, by the presence of foreset bedding. Lake levels commonly dropped during delta formation, thus several deltas can be incised or "telescoped" into each other (Plate 2-7). On the map some of these telescoped deltas are shown as one unit since they are too small to differentiate and are part of the same delta system.

Glaciofluvial complex (Gx)

Sediments of glaciofluvial complex are generally >5 m thick and form terraces, kettle holes, crevasse fillings, and eskers. A typical example is the complex along the Pelly River at The Detour (Plate 2-2). These deposits occur throughout the map area, reflecting the regional stagnation style of deglaciation, but are most common in valley bottoms and on plateaus. The

sediments are dominantly poorly sorted, weakly to unstratified gravel and sand, but may contain diamicton and silt.

Glaciolacustrine plain (Lp)

Glaciolacustrine plain sediments are generally >5 m thick and were deposited in relatively long-lived glacial lakes. This unit is widespread in the Macmillan River valley and along the west side of Little Salmon Lake, and is exposed in sections along the Pelly, Tay, and Little Salmon rivers (Maps 1786A, 1787A, 1788A, 1789A). The unit is dominated by well stratified sand, silt and clay (Plate 2-5), and can be capped by thin, discontinuous gravel deposited after the lakes drained. Segregated ice lenses, retrogressive thaw slides (Plate 2-6) and thermokarst lakes. are abundant in glaciolacustrine plain sediments

Glaciolacustrine Blanket and Glaciolacustrine Veneer (Lb and Lv)

Glaciolacustrine blankets and veneers are >1 m and <1 m thick, respectively. The sediments were deposited either in short-lived lakes or at low sedimentation rates. These units are found throughout the map area and are especially common in the southern and western sectors and along creeks in the Glenlyon Range where the drainage was blocked during deglaciation. The sediments are similar in character to those of glaciolacustrine plains.

Glaciolacustrine complex (Lx)

Sediments mapped as glaciolacustrine complex are generally >5 m thick. They are much more disturbed than other glaciolacustrine deposits showing ample evidence of slumping, folding, and faulting (Plate 2-5B). They also contain more gravel and diamicton than other glaciolacustrine units, since

they were deposited in ice-proximal settings. This unit commonly occurs in the larger valleys where stagnant ice dammed large glacial lakes.

Holocene

Eolian deposits (E)

Eolian deposits >1 m thick are rare in the map area. An extensive area of now stabilized and vegetated parabolic dunes occurs in the south-central part of the map area (Plate 2-3) (Map 1788A) and gently undulating eolian sands are present on a glaciofluvial terrace along the Yukon River (Map 1788A). There are many cliff top dunes above sections along streams and rivers, but these are too small to show on the maps.

Organic deposits (O)

Organic deposits range from 1 to 5 m in thickness and are common throughout the map area on low-lying or gently sloping surfaces such as floodplains, lake margins, shallow depressions, and some poorly drained slopes. Permafrost is very common in these deposits as indicated by associated peat palsas and thermokarst lakes.

Alluvial plain (Ap)

Alluvial plain sediments are >1 m thick and can be considerably thicker. They occur on the present floodplains of rivers and streams. The width of the floodplain is controlled by the overall width of the valley. The Pelly River floodplain ranges from just over 200 m at The Detour, where a thick sequence of late-glacial sediments confine the channel, to over 3.5 km at Safety Pin Bend.

Sediments in channel bars and channel bottoms consist mainly of sand and gravel. Floodplains are generally underlain by sand and silt deposited during floods. Overbank areas can also contain minor amounts of non-alluvial deposits, such as lacustrine and organic sediments. Alluvial plains are subject to periodic flooding, and areas along active channels of rivers may be affected by ice push during spring breakup.

Alluvial terrace (At)

Alluvial terrace sediments are 1-5 m thick and represent old river channel deposits. They border all rivers and streams in the map area but are best developed along the larger rivers (Plate 2-2); on smaller rivers and streams they are generally combined with the present floodplains as "alluvial undivided" (Au). Alluvial terrace sediments generally consist of moderately stratified, well imbricated gravel which either grades into, or is abruptly capped by sand and silt.

Alluvial fan (Af)

Alluvial fan sediments are more than 2 m thick and can be considerably thicker. They are found throughout the map area but are especially common in mountainous areas. The steepest fans are dominated by debris flow and avalanche processes, while more gentle sloping fans are dominated by fluvial deposition. Alluvial fans can coalesce, so that one map unit may comprise two or three individual fans. Both active and inactive alluvial fans occur. Paraglacial fans formed immediately after deglaciation when unvegetated slopes were covered with abundant unstable, unconsolidated material (cf. Church and Ryder, 1972). These fans are generally inactive now, and in many cases have been incised by a stream flowing across them.

Steep alluvial fans are dominated by diamicton and poorly sorted gravel deposited by debris flows and avalanches. As the fan gradient decreases the proportion of fluvial deposits increases and is represented by better sorted gravel with minor sand.

Alluvial undivided (Au)

Alluvial undivided sediments are thicker than 1 m. This unit was applied along streams and confined river valleys where it is not possible to separate the present floodplain from terraces and fans at the scale of mapping. Sediment types are similar to those found in alluvial plains, terraces, and fans, but in steep terrains the unit can contain significant amounts of colluvial deposits along valley sides.

Colluvial blankets and colluvial veneers (Cb, Cv)

Colluvial blankets and veneers are >1 m and <1 m thick, respectively. Although rare in the map area, they occur predominantly in alpine areas, often above the McConnell limit on slopes not steep or extensive enough to form colluvial aprons. They generally consist of solifluction lobes or other permafrost related features and are composed of stony diamicton or rubble.

Colluvial aprons (Ca) and bouldery colluvial aprons (bCa)

Colluvial apron sediments, up to 10 m thick, are very common in the map area, occurring on most sediment-covered slopes steeper than 20°. They commonly consist of colluviated glacial diamicton. The diamicton is weakly stratified parallel to the slope and more porous than glacial diamicton; it may contain organic material incorporated during downslope movement and sorted material deposited by slopewash.

Bouldery colluvial apron sediments, to 10 m thick, are the only map unit separated on the basis of texture. They occur exclusively in alpine areas, usually at the base of steep bedrock slopes mapped as R-A. They consist of blocks and rubble derived from local bedrock.

Stratigraphy

The stratigraphic framework for glaciations in the central Yukon is described in **REGIONAL QUATERNARY CONTEXT**. In summary, the stratigraphic framework is related to the McConnell, Reid, and pre-Reid glaciations and the nonglacial intervals that separate them. Stratigraphic relationships and relative ages can be inferred from the spatial distributions of deposits of different glaciations. However, most of the stratigraphy reported here was obtained from natural exposures along streams and rivers. The age of sediments underlying McConnell glacial deposits in these exposures is difficult to determine because contacts commonly are erosive and because material suitable for dating is rare. The locations of exposures from the Glenlyon map area are indicated on Maps 1786A through 1789A, and exposures to the west of this area are indicated in Fig. 2-2.

Pre-Reid Glaciations

Surficial deposits correlated to one of the pre-Reid glaciations are exposed at the surface in the western part of the map area (Maps 1786A and 1788A). They are characterized by a very subdued landscape, indicative of their antiquity. No deposits examined in sections were correlated to any of the pre-Reid glaciations.

Deposits Prior to the Reid Glaciation

The oldest sediments identified in section are units 1 and 2 at the Bradens Canyon section (Figs. 2-2, 2-11)(Ward, 1989) This site is beyond the limit of the McConnell glaciation but within the limit of the Reid glaciation (Fig. 2-2).

Units 1 and 2 are dominantly sands with the former containing scattered pebbles and gravely lenses. Unit 1 contains two large, up to 140 cm wide and >150 cm in depth, composite wedge casts (cf. French, 1976, pg. 239) overlain by interstratified fine-grained organic layers, sand and gravel (Plate 2-12A). There is no evidence of pedogenesis associated with these layers (S. Smith, Agriculture Canada, personal communication, 1991). The detrital organic layers yielded a radiocarbon age of >41,000 yr BP (GSC-4510). Pollen recovered from these sediments is poorly preserved, and consists mainly of indeterminate grains with minor amounts of *Picea* (spruce), *Betula* (birch), Chenopodiaceae (goosefoot) and Gramineae (grasses). Macrofossils, consisting mainly of small wood fragments and fungal sclerotia, are also poorly preserved and were not identified. The organics and associated mineral sediments are convoluted and are cut by at least two small composite wedge casts (Plate 2-12B). Paleomagnetic data indicates that Unit 1 was deposited during the Brunhes Normal Polarity Chron (Jackson *et al.*, 1990). Unit 2 consists of well stratified, ripple and trough crossbedded, fine to medium sand with no obvious permafrost features. At the upstream end both units are truncated by a thin diamicton (Unit 3A). Associated with this contact are drag folding and thrust faults, with organics from unit 1 having been thrust over unit 2

The units are interpreted to indicate the following sequence of events. Unit 1 was deposited by fluvial processes. Its upper surface was exposed

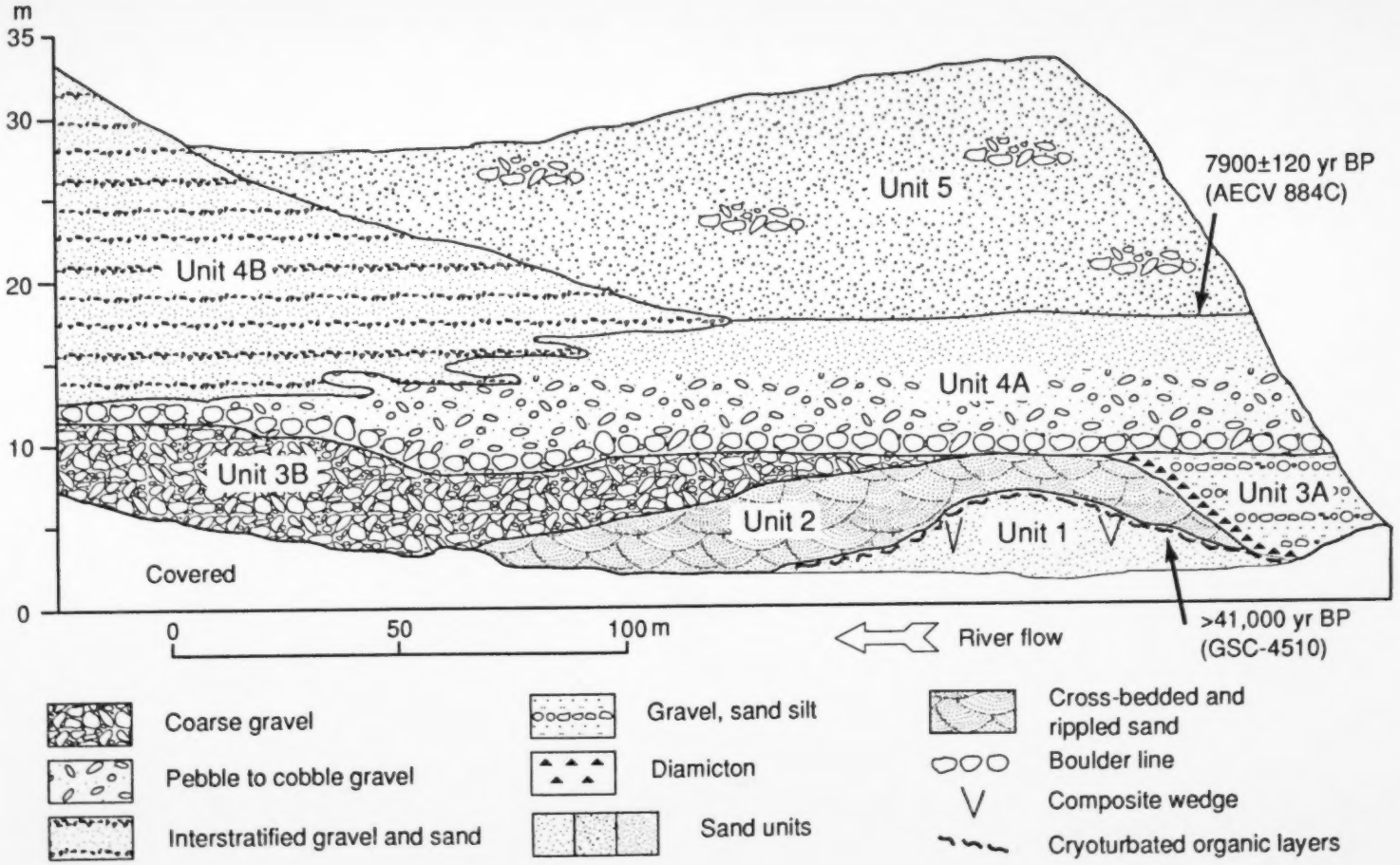
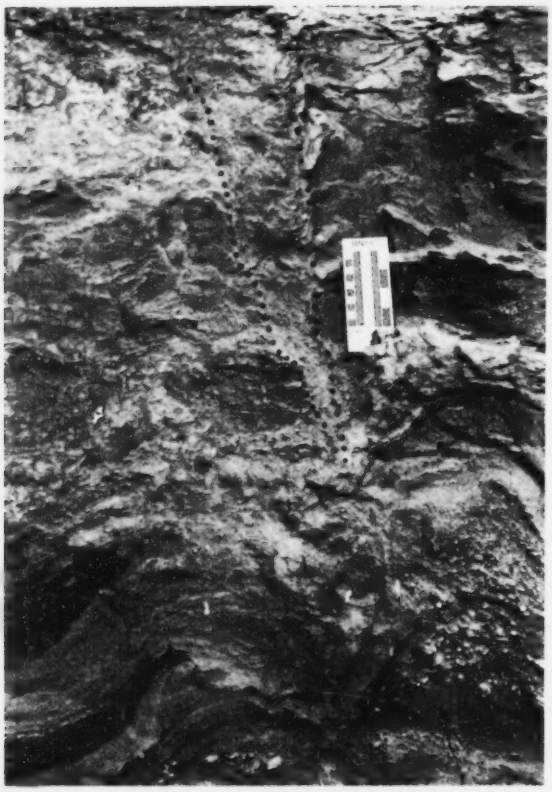


Figure 2-11: Bradens Canyon section, see Fig. 2-2 for location.

A



B

Plate 2-12: Cryogenic features in unit 1 at the Bradens Canyon section. A: Small composite wedge in the upper part of unit 1. B: Large composite wedge (outlined) overlain by cryoturbated organic layers (arrowed), sand and gravel. Visible portion of the ice axe is 90 cm long.

during a periglacial climate causing the development of the large composite wedges. Their large size indicates a considerable period of subaerial exposure (cf. French, 1976, p. 87). Floods deposited fine-grained detritus and organic material that were subsequently cryoturbated and cut by small composite wedges. Subaerial exposure is also indicated by the presence of fungal sclerotia (J. Matthews, Geological Survey of Canada, personal communication, 1991). However, the climate was harsh enough that little or no pedogenesis took place. With the deposition of Unit 2, river aggradation apparently was sufficiently rapid that permafrost did not have time to affect the unit. The thrust faults and folds are attributed to glacial deformation (Ward, 1989). Based on the paleomagnetic data (Jackson *et al.*, 1990) and the section's relative location, it was Reid ice that overran the two units causing deformation.

Reid Glaciation

Reid deposits are exposed at the surface at a higher elevation and beyond the limit of the McConnell glaciation (Maps 1786A, 1787A, 1788A, 1789A), in a sections along the Pelly River downstream from the McConnell limit, including the Bradens Canyon, Pelly Farm and Granite Canyon section, and at one site within the McConnell limit, the Drury Creek section.

Bradens Canyon section (Fig. 2.2)

The deposition of unit 3 has been attributed to the Reid glaciation. Unit 3A at the Bradens Canyon section consists of a thin diamicton subunit and interstratified sand, silt and gravel. Unit 3B consists of moderately stratified cobble and boulder gravel. The thin diamicton subunit of unit 3A is interpreted as a till on the basis of its association with glaciotectonic features and the rest of the unit likely represents glaciolacustrine sedimentation (Ward, 1989). The

coarse gravel of unit 3B is interpreted as glaciofluvial deposition. Units 4A and B are described in **McConnell Glaciation** and Unit 5 in **Holocene**.

Granite Canyon section

Several exposures of silt and sand occur below McConnell and Holocene gravel, downstream of Granite Canyon, including the Granite Canyon section. (Fig. 2-2, Plate 2-13A). Unit 1 at the Granite Canyon section consists of ~15 m of thinly bedded to laminated fine sand, silt and minor clay. Based on the location this section is interpreted as Reid glaciolacustrine sediment deposited during deglaciation.

Pelly Farm section

The Pelly Farm section, occurs in a high terrace near the limit of the Reid glaciation (Figs. 2-2, Plate 2-14A) that has been interpreted as Reid glaciofluvial (Klassen *et al.*, 1987). Most of the section consists of a thick sequence of gravel with minor sand. At the top of this gravel sequence a paleosol is developed. The soil has a well developed Bm horizon, 10-15 cm thick, with hues of 7.5YR to 10YR. Some metamorphic and volcanic clasts >2 mmin the uppermost 1 m of the gravel unit are slightly chemically weathered and other clasts, including some sedimentary, are fractured, likely due to frost shattering but no ice wedge pseudomorphs were observed. This soil appears similar to the Diversion Creek paleosols (S. Smith, Agriculture Canada, personal communication, 1991). Based on the composition of the sediments, its location and the presence of a paleosol similar to the Diversion Creek soil, the section is interpreted as representing Reid glaciofluvial deposition.

Lyon Creek section

Deposits that have been tentatively assigned to the Reid glaciation have been identified at Lyon Creek, north of Drury Lake, well inside the McConnell limit (Fig. 2-2, Plate 2-7). A brief description of the units at the Lyon Creek

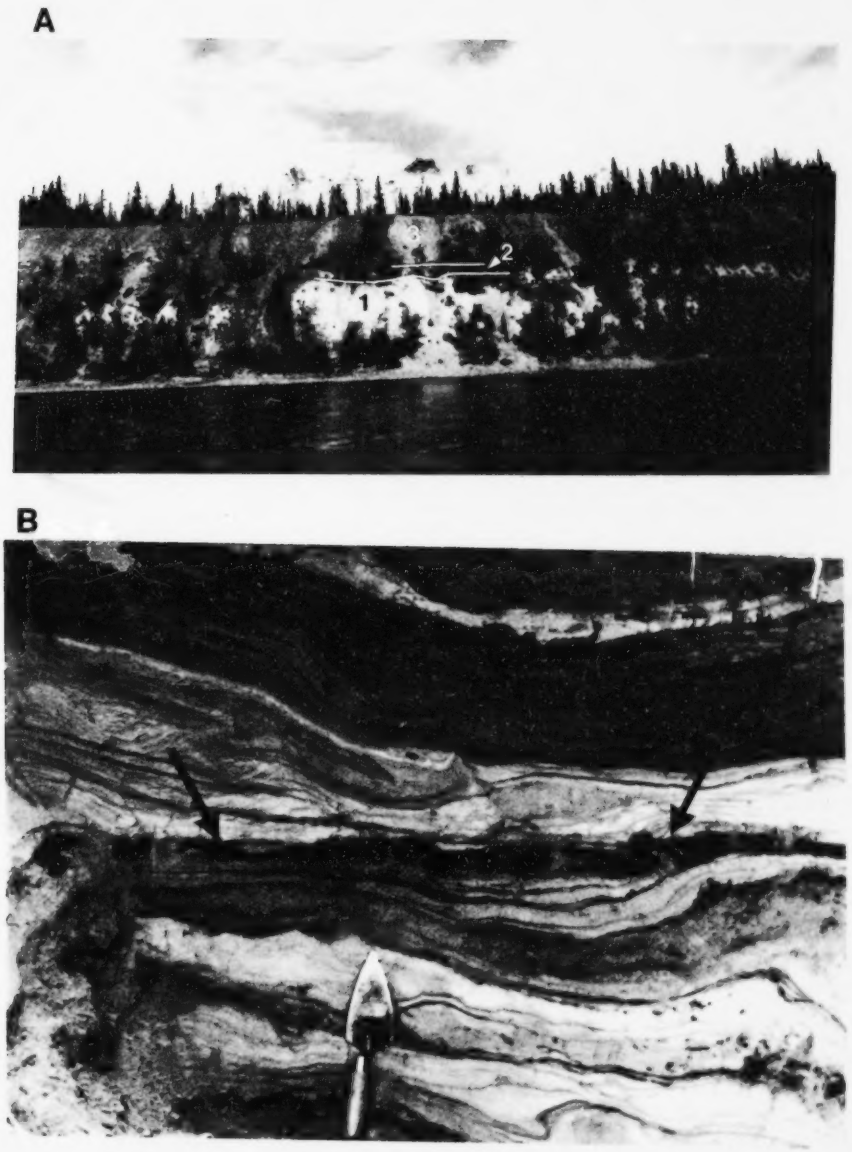


Plate 2-13: Granite Canyon section; see Fig. 2-2 for location. A: Section with contacts of units highlighted. Section is 29 m high. B: Organic layer RC-1, Unit 2 is arrowed. Trowel is 25 cm long.

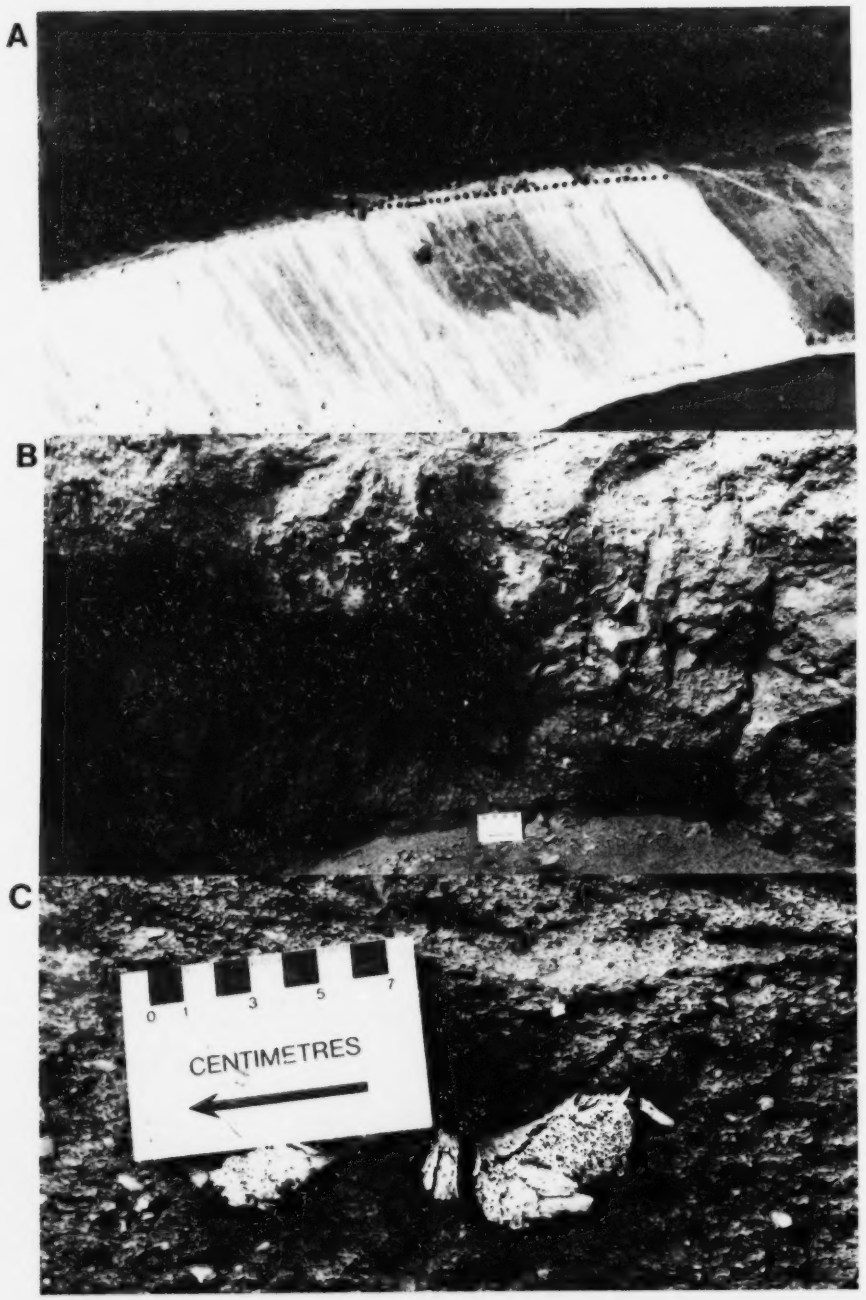
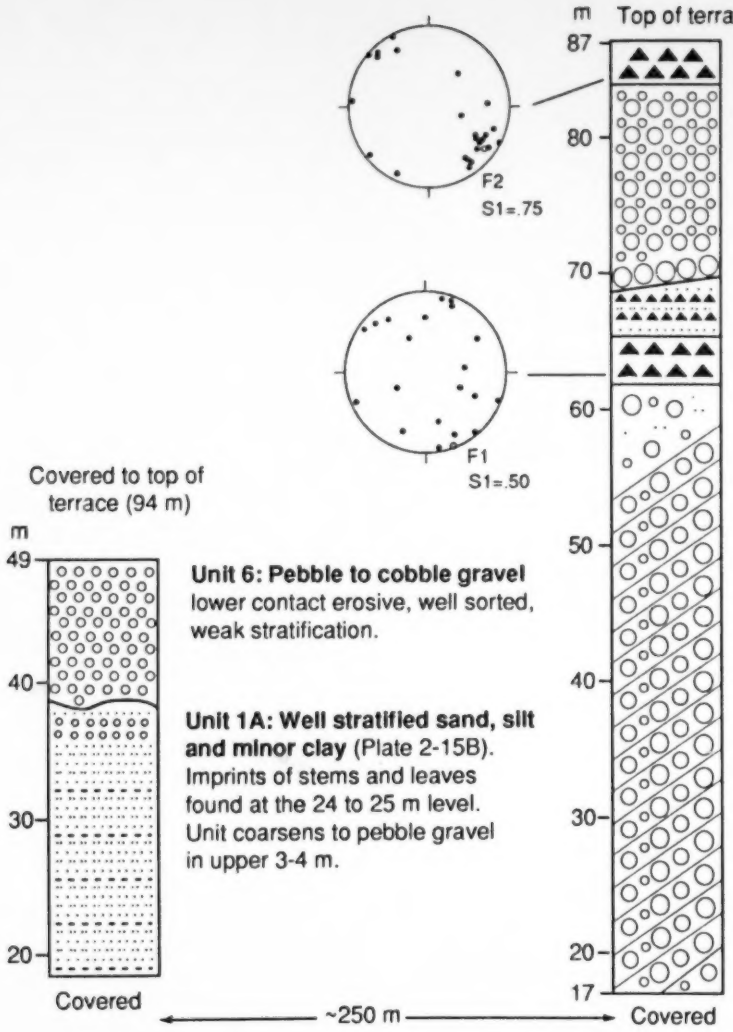


Plate 2-14: Pelly Farm Section, location given in Figure 2-2. A: Section is 75 m high. B: Cryogenic features in alluvial unit, scale in cm. C. Bones in alluvial unit.

section is given in Fig. 2-12. Unit 1A (Plate 2-15B) consists of well stratified silt and fine sand and imprints of stems and leaves were found in the lower 5 m. Unit 1B consists dominantly of large-scale foreset bedded sand and gravel (Plate 2-15A) although the upper 4 to 5 m being highly disrupted and brecciated. Greater than 95% of the clasts >2 mmpresent are granitic and many of these are weathered and some are grusified. The diamicton of unit 2 is dense and massive and clasts, although dominated by granitic, also contain sedimentary and volcanic rock types. The clast fabric (F1, S1=.5) appears random. The lower contact is irregular with clastic dikes of diamicton and sorted sediment extending down, dipping towards the northwest, into unit 1 (Plate 2-15C). Unit 3 consists of interstratified diamicton, gravel and sand, and unit 4 is a coarse gravel. Unit 5 consists of dense, massive diamicton that forms the upland surface in the area (Plate 2-7). A clast fabric from this diamicton has a pronounced clustering (F2, S1=.75) oriented northwest-southeast. It has a sharp, erosive contact that truncates weathered pebbles and cobbles in unit 4.

Units 1, 2, 3, and 4 are interpreted to represent the following sequence of events during the Reid glaciation, although, in the absence of dating control, an even older age is possible. Unit 1B is interpreted as a deltaic sequence, deposited during advance in an ice dammed lake in which unit 1A was deposited. This lake was at least 62 m higher than the present Drury Lake. The clastic dikes at the base of unit 2 are interpreted as till wedges and their orientation indicates glacier flow towards the northwest (cf. Aber *et al.*, 1989). These wedges and the dense, massive nature of the diamicton of unit 2 suggest that it is a till. However, the weak strength of the fabric could indicate that it has been remobilized. Unit 3 and 4 likely represent glaciolacustrine and glaciofluvial deglacial sedimentation, respectively. The highly weathered



Unit 6: Pebble to cobble gravel lower contact erosive, well sorted, weak stratification.

Unit 1A: Well stratified sand, silt and minor clay (Plate 2-15B). Imprints of stems and leaves found at the 24 to 25 m level. Unit coarsens to pebble gravel in upper 3-4 m.

Unit 5: Diamicton, dense, generally massive, lower contact sharp and erosive.

Unit 4: Boulder to cobble gravel, coarsest at the base, no grading or stratification evident above. Clasts and sand dominated by granitic lithologies. Iron staining and weathered clasts present, especially at the base. Lower contact erosive.

Unit 3: Interstratified diamicton, sand and silt, lower contact gradational.

Unit 2: Diamicton, generally massive, very dense. Clasts dominated by granitic lithologies but some sedimentary and volcanic rocks present. Lower contact marked by till wedges (Plate 2-15C).

Unit 1B: Gravel. At main exposure, unit consists of coarse, foreset-bedded gravel that is intensely iron stained and contain many weathered and grusified clasts (Plate 2-15A). To the northeast the unit grades into pebbly sand and chaotic gravel. Upper 4-5 m is a melange, it is highly disrupted, brecciated and appears mixed togeather. All of subunit cut by abundant clayey silt clastic dikes. Clasts in this unit are almost entirely granitic, as is the sand.

Figure 2-12: Lyon Creek section, section 40 (Map 1789A). Elevation datum is Drury Lake. Location given in Fig. 2-2 and Plate 2-7

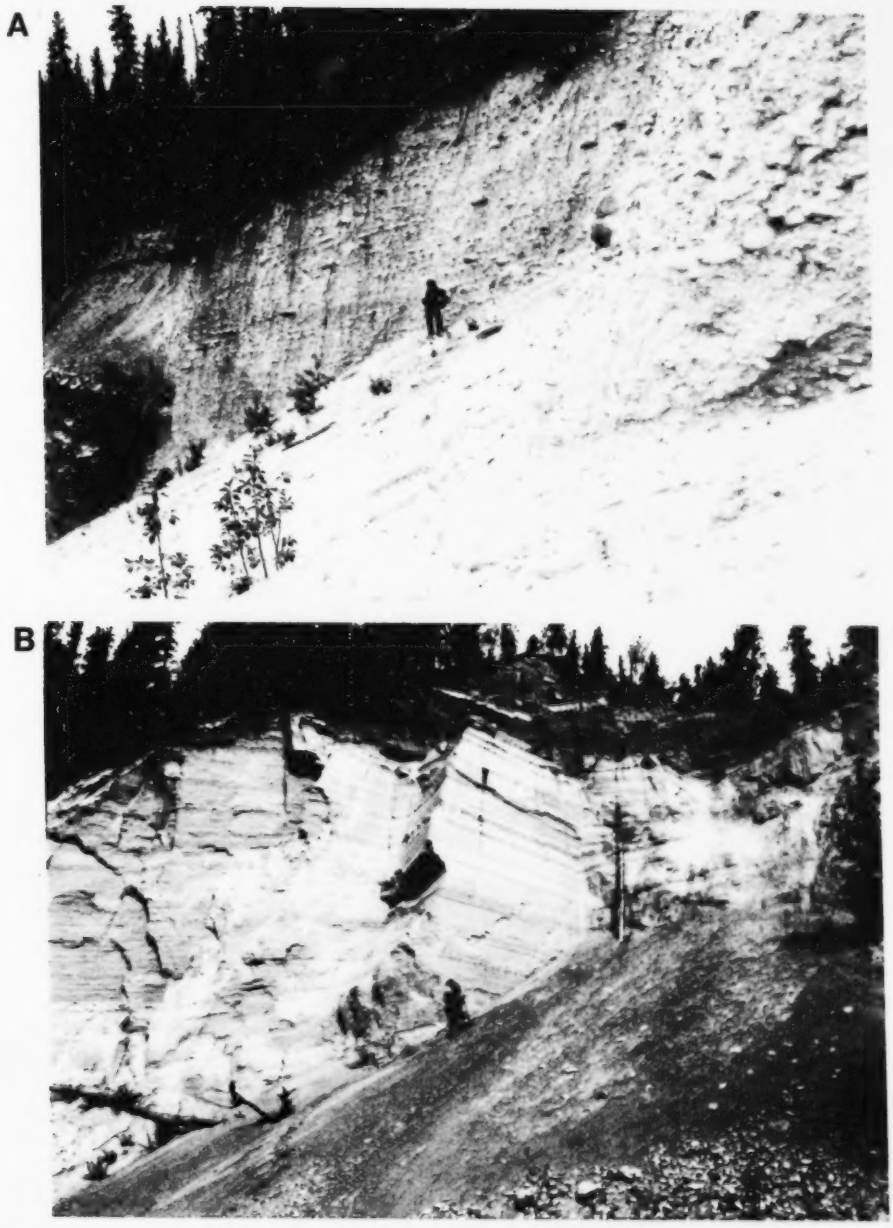


Plate 2-15: Lyon Creek section, section 40 (Map1789A); see Fig. 2-2 for location. 15A: Large foresets, unit 1b. 15B: Well stratified glaciolacustrine sediments, unit 1a.

C

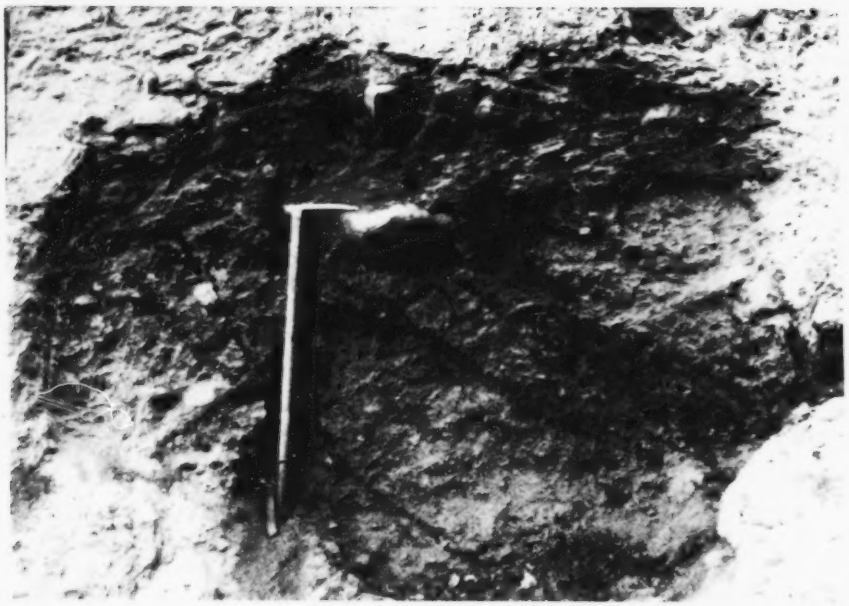


Plate 2-15 (Continued): Lyon Creek section, section 40 (Map1789A); see Fig. 2-2 for location. 15C: Detail of lower contact, unit 2. Clastic dikes of diamicton and sorted material have been injected into underlying sediments. Indicated clast (arrow) has been fractured and infilled. Ice axe is 90 cm long.

nature of the granitic boulders and the extensive iron staining indicate that these units are older than the McConnell glaciation. There are differences in the degree of weathering between units 1 and 4; unit 1 has more extensive iron staining and contains more grusified clasts >2 mmthan unit 4. This could be caused by differences in groundwater flow or by a significant difference in the ages of the two units.

Koy-Yukon Thermal Event

No deposits attributed to the Koy-Yukon thermal event were identified in the study area. However, the truncated paleosol at the top of the Pelly Farm section appears similar to the Diversion Creek paleosols (S. Smith, Agriculture Canada, personal communication, 1991), which likely formed during the last interglaciation (Tarnocai *et al.* 1985; Smith *et al.* 1986).

Middle Wisconsinan Interstade

Three sites, Granite Canyon, Pelly Farm, and Section 26, were found to have deposits that pre-date the McConnell glaciation and postdate the Koy-Yukon thermal event.

Granite Canyon section

The Granite Canyon section, which is located just beyond the McConnell limit, contains unit 2 (Fig. 2-2, Plate 2-13A). Unit 2 erosively underlies the coarse gravel of unit 3, interpreted to have been deposited by a catastrophic flood that occurred during McConnell deglaciation (Lye *et al.*, 1990). Unit 2 consists of 3.5 m of a fining upward sequence of gravel, sand and silt which dip gently towards the present river. The upper ~1.5 m contains two organic layers and sand which is extensively iron stained (Fig. 2-13B). A bulk sample from the upper organic bed, RC-1, yielded a conventional

radiocarbon age of 36,060 ± 2,000 yr BP (AECV 1422C), and charcoal from the sand bed immediately below gave an accelerator radiocarbon age of 37,120 ± 350 yr BP (TO-1278). Organic layer RC-1 contains abundant insect macrofossils (Table 2-2), and both RC-1 and M-7, approximately 1 m below RC-1, contain abundant pollen (Table 2-3).

Unit 2 is interpreted as an Middle Wisconsinan alluvial deposit based on the radiocarbon ages and the stratigraphic position below McConnell gravel. A cautionary note is required about the radiocarbon ages. Isotrace (TO) always gives an apparent age for samples, regardless of their actual age. Thus, the accelerator radiocarbon age of 37,120 ± 350 yr BP (TO-1278) could be non-finite, even though in this time range the age should be valid (R. McNeely, Geological Survey of Canada, personal communication, 1992). Further confidence is added by the conventional radiocarbon age of 36,060 ± 2,000 yr BP (AECV 1422C). Since these ages are close to the radiocarbon dating limit there is a possibility that they are minima and that these sediments predate the Middle Wisconsinan; however a Middle Wisconsinan age is currently thought to be the most likely interpretation.

The insect macrofossils and pollen allow for paleoenvironmental reconstruction. The insect assemblage includes several genera of bark beetles and planthoppers and appears to indicate the presence of forest, although plant macrofossils are lacking. Also, ground beetles in these sediments are found today south of tree line, and ants extend only slightly beyond tree line today. As well, the sample lacks fossils that are found only in tundra regions. The pollen assemblage of samples RC-1 and M7 are dominated by *Picea* (spruce), also indicating forested conditions, likely a boggy/muskeg community consisting of *Picea mariana* (black spruce) and Cyperaceae (sedge) (H. Friebe, University of Alberta, personal

FOSSILS	15789RC1	15789-M7
TUBELLARIA - "flatworms"	?cocoons	
ARTHROPODA		
INSECTA		
HOMOPTERA		
Cicadellidae - "leafhoppers"		
Genus?	head	
Fulgoridae - "planthoppers"		
Genus?	heads	
COLEOPTERA - "beetles"		
Carabidae - "ground beetles"		
Elaphrus lapponicus Gyll.	pronota, elytra	
Bembidion morulum Lec.	elytra, pronota	
Pterostichus (Cryobius) hudsonicus Lec.	pronota	
Pterostichus (Cryobius)sp.	elytra	
Dytiscidae - "predaceous diving beetles"		
Genus?	elytra &pronota fragments	
Hydrophilidae - "water scavenger beetles"		
Hydrobius sp.	head fragment	
Genus?		thorasic fragment
Staphylinidae - "rove beetles"		
Olophrum rotundicolle (Sahlb.)	elytra, pronota	
Olophrum latum Makl.	pronota	
Holoboreaphilus nordenskioeldi(Makl.)	cf (elytron)	
Stenus sp.	head, pronota	
Quedius sp.	head, pronota	
Aleocharinae	pronota, head	
Scarabaeidae - "scarab beetles"		
Genus?		elytral fragment
Coccinellidae - "ladybird beetles"		
Genus?	poorly preserved pronotum	
Chrysomelidae - "leaf beetles"		
Genus?	elytral fragment	
Curculionidae - "weevils"		
Genus?	leg	
Scolytidae - "bark beetles"		
Genus (several)	heads, pronota, elytra	
DIPTERA - "flies"		
Family?	puparial fragments	
HYMENOPTERA - "wasps and ants"		
Symphyta - "sawflies"		
Tenthredinidae	head	
Apocrita		
Genus?	head and propodeal fragment	
Formicidae - "ants		
Formica typ.	head	
ARACHNIDA		
Acari - "mites and ticks"		
Oribatei - "oribatid mites"		
Family?	+	
Araneae - "spiders"		
Family?	+	

Table 2-5: Insect macrofossils identified from unit 2, Granite Canyon Section (John Matthews, Unpublished Geological Survey of Canada Fossil Arthropod Report 91-24.

Pollen Type	RC-1		M7	
Picea (spruce)	160	66.4%	192	82.8%
Cyperaceae (sedge)	72	29.9%	19	8.2%
Salix (willow)			11	4.7%
Gramineae (grasses)	5	2.1%	3	1.3%
Betula (birch)	1	0.4%	2	0.9%
Valerianaceae (Valerian)			4	1.7%
Ericaceae (heather)			1	0.4%
Compositeae	3	1.2%		
	n=241		n=232	

Table 2-6: Pollen data from organic layers RC-1 and M-7, unit 2, Granite Canyon section (Pollen data was identified and interpreted by H. Friebe (University of Alberta, personal communication).

communication, 1991). These data represent forested conditions during the Middle Wisconsinan in the Pelly River basin.

Pelly Farm section

The Pelly Farm section (Fig. 2.2) contains a wedge of disturbed, pebbly sand which covers the Koy-Yukon thermal event paleosol at the upstream end of the section (Plate 2-14A). This wedge of sediment forms a fan like feature. The disturbances of the sediment include warped strata and wedge-shaped inclusions of vertically oriented pebbles (Plate 2-14B). Fragmented bones of a large ungulate (Plate 2-14C), possibly *Bison sp.* (C. R. Harington, National Museum of Canada, personal communication, 1987) were recovered from these sediments. The upper contact of this unit with the overlying loess is marked by ventifacted pebbles.

Based on the morphology of the deposit, its stratigraphic position above the paleosol, the wedge shaped disturbances and the ventifacted upper contact, this deposit is interpreted as an alluvial fan deposited after the Koy-Yukon thermal event and before the McConnell glaciation. The wedge shaped disturbances are interpreted to be cryogenic structures, the ventifacted pebbles are interpreted as representing erosion by katabatic winds, and both are thought to have formed during the McConnell glaciation. Thus, the sediments were deposited sometime in the Wisconsinan before or during the initiation of the McConnell glaciation.

Section 26

Section 26 (Ward, 1989) occurs well within the McConnell limit (Fig. 2.2) and units 1 to 4 underlie McConnell glacial sediments (Fig. 2-13). Units 1 and 2 were only exposed in an excavation at the downstream portion of the section. Unit 1 consists of gravel, sand and minor silt, and unit 2 consists of astony diamicton with some striated clasts. Unit 3 consists of a well stratified,

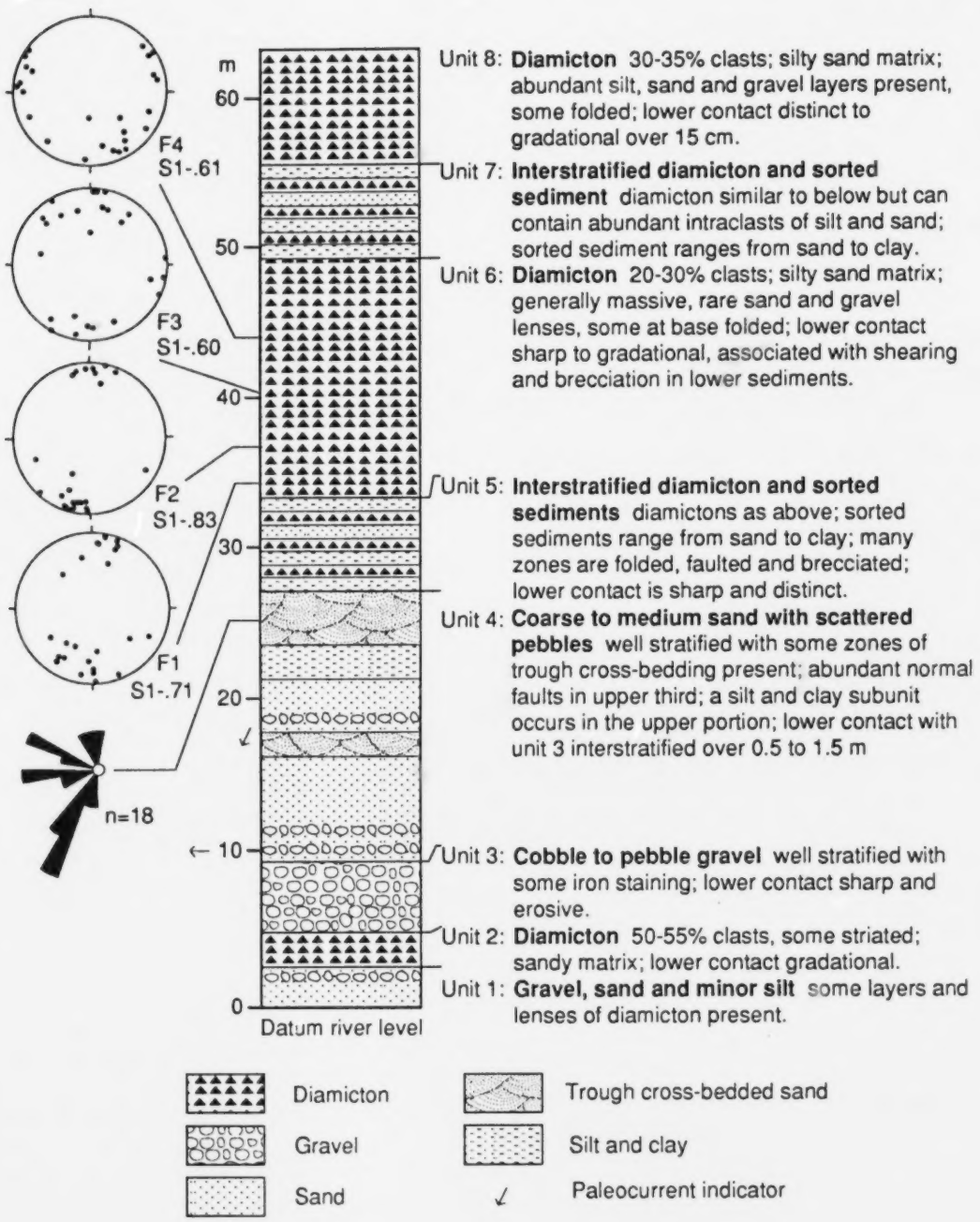

m
60
50
40
30
20
10
0
F4
S1-.61
F3
S1-.60
F2
S1-.83
F1
S1-.71
n=18
Datum river level
Unit 8: Diamicton 30-35% clasts; silty sand matrix; abundant silt, sand and gravel layers present, some folded; lower contact distinct to gradational over 15 cm.
Unit 7: Interstratified diamicton and sorted sediment diamicton similar to below but can contain abundant intraclasts of silt and sand; sorted sediment ranges from sand to clay.
Unit 6: Diamicton 20-30% clasts; silty sand matrix; generally massive, rare sand and gravel lenses, some at base folded; lower contact sharp to gradational, associated with shearing and brecciation in lower sediments.
Unit 5: Interstratified diamicton and sorted sediments diamictons as above; sorted sediments range from sand to clay; many zones are folded, faulted and brecciated; lower contact is sharp and distinct.
Unit 4: Coarse to medium sand with scattered pebbles well stratified with some zones of trough cross-bedding present; abundant normal faults in upper third; a silt and clay subunit occurs in the upper portion; lower contact with unit 3 interstratified over 0.5 to 1.5 m
Unit 3: Cobble to pebble gravel well stratified with some iron staining; lower contact sharp and erosive.
Unit 2: Diamicton 50-55% clasts, some striated; sandy matrix; lower contact gradational.
Unit 1: Gravel, sand and minor silt some layers and lenses of diamicton present.
Diamicton
Gravel
Sand
Trough cross-bedded sand
Silt and clay
Paleocurrent indicator

Figure 2-13: Section 26, location shown Fig 2-2. Stereonets of fabric data from unit 6 and a rose diagram of current indicators for unit 4 are displayed along the side.

cobble to pebble gravel that generally fines upward. Unit 4 consists of a thick sequence of sand with minor gravel. Some of the sand contains trough cross-beds that indicate flow generally downvalley. Poorly preserved detrital wood was found in the sand. A silt and clay subunit occurs near the top of the unit.

Based on stratigraphic position units 1 to 4 predate the McConnell glaciation. Interpretation of units 1 and 2 is problematic because their lateral extent in unknown. The striated clasts in unit 2 suggest a glacial origin but the unit could be reworked from an older glacial deposit. Unit 3 is interpreted as interstadial fluvial gravels on the basis of its stratified nature and stratigraphic position. The thick sand of unit 4 record river aggradation, likely as McConnell glaciers advanced into the area. The fine sand and silt layer near the top of the sand represent a ponding event before the site was overrun by the ice. This ponding event has been interpreted as caused by ice advancing down the Macmillan River valley, blocking the Pelly River (Ward, 1989).

McConnell Glaciation

Deposits of the McConnell glaciation occur throughout the study area. Although most of these sediments were deposited during deglaciation, some were deposited during the advance, such as Measured Section 12 (Map 1787A), Measured Section 29 (Map 1786A) and Section 26 (Fig. 2.2), described above.

Measured Section 12 (Map 1787A) occurs along Little Sheep Creek within the Glenlyon Range. It exposes two glaciolacustrine units separated by a till. The lower glaciolacustrine unit was deposited when the Selwyn Lobe in the Tintina Trench blocked the drainage, forming a lake. The site was later covered by ice. During deglaciation, ice persisted in the Tintina Trench after Little Sheep Creek was deglaciated, forming a second lake.

Measured Section 29 (Map 1786A) is located at Safety Pin Bend and exposes two tills separated by thick stratified sediments which is described in more detail by Ward (1989). The lower half of the stratified sediments consist of interstratified gravel, sand, silt and minor diamicton which fines upward. The upper portion of the stratified sediments consist of a coarsening upward sequence of interstratified sand and gravel that is in conformable contact with the lower sediments. The upper stratified sediments are erosively truncated by a diamicton, interpreted as a till, that forms the upland surface in the area. This sequence of stratified sediments is interpreted as a conformable retreat-advance sequence. This suggests that there were two distinct advance phases of the McConnell glaciation, representing a large oscillation of the ice front.

Units 4A and B at the Bradens Canyon section (Fig. 2-2, 2-11) were deposited during the McConnell glaciation (Ward, 1989). Unit 4A has a lower contact marked by a boulder line and consists of a overall fining upward sequence from cobble gravel to sand and silt. The elevation of the upper contact corresponds well to the gradient of McConnell terraces measured between Bradens Canyon and the McConnell limit at Granite Canyon. Unit 4B consists of interstratified poorly sorted gravel and sand with minor diamicton with the stratification dipping towards the river. The contact between the two units is interfingering and the upper surface of both units are marked by a weak brunisolic paleosol. Peat layers associated with this paleosol at the lowest elevation yielded a radiocarbon age of 7900 $\pm$ 120 (AECV 884C). Unit 4A is interpreted as distal outwash deposited from the maximum position at Granite Canyon based on the elevation of its upper surface, the paleosol and the radiocarbon age. Unit 4B is a coeval alluvial fan that prograded into the river that deposited unit 4A.

Holocene

Holocene deposits occur throughout the map area consisting of coluvial deposits along present slopes, alluvial deposits along present streams and rivers, organic deposits in low lying areas and aeolian deosits throughout the map area. Holocene deposits are indicated at the tops of some of the measured sections and unit 5 at the Bradens Canyon section (Fig. 2-2, 2-11). Unit 5 consists mainly of sand with occational gravelly lenses. It is interpreted as having been deposited by a low gradient alluvial fan at some time after 7900 ± 120 (AECV 884C).

QUATERNARY HISTORY

The landscape of the Glenlyon map area formed in response to geologic events in the Tertiary and has subsequently been modified by glaciations, widening valleys and altering drainage patterns, in the Pleistocene. The Quaternary included nonglacial periods during which conditions were broadly similar to the present and glacial periods when conditions were colder than today and glaciers covered much of southern and central Yukon.

Pre-Reid Glaciations

Pre-Reid deposits in central Yukon are Early Pleistocene in age (Jackson *et al.*, 1991). Little is known of conditions during these glaciations, but it can be assumed that ice originated from similar sources and had similar flow directions as during younger glaciations. The greater extent of ice cover during these early glaciations than during the Reid and McConnell glaciations (Fig.2-1) may have been caused by greater precipitation in the source areas of

the Selwyn, Pelly and Cassiar mountains as a result of the lower elevations of the St. Elias Mountains during the early Pleistocene (Jackson *et al.*, 1991).

There is uncertainty about the number of pre-Reid glaciations. At least two pre-Reid glaciations (Jackson *et al.*, 1990), and possibly three (Tarnocai and Schweger, 1991), affected central Yukon. Three pre-Reid glaciations have been reported from the Liard Plain of southwestern Yukon (Klassen, 1987); these are younger than the pre-Reid glaciations of central Yukon (Jackson *et al.*, 1991). There have been at least four pre-Reid glaciations in the Mackenzie Mountains, N.W.T. (Tarnocai and Schweger, 1991).

Pre-Reid glaciers likely covered most, if not all, of the peaks in the Glenlyon Range and the lower hills in the western portion of the map area. The presence of highly weathered bedrock in the Glenlyon Range (Plate 2-11) can be explained by the great antiquity of the pre-Reid glaciations: more than 1 m.y. separated the youngest pre-Reid and the Reid glaciations (L. E. Jackson, Jr., Geological Survey of Canada, personal communication, 1992)

Pre-Reid Interglaciations

Most of the data on pre-Reid interglaciations comes from paleosols developed on glacial deposits of pre-Reid age. Wounded Moose paleosols (Tarnocai *et al.*, 1985; Smith *et al.* 1986) are found on pre-Reid glacial deposits in the Stewart River valley. This soil may be the product of pedogenesis during several interglaciations. The presence of montmorillonite indicates an initial period of warm subhumid climate with grassland shrub vegetation (Foscolos *et al.*, 1977; Rutter *et al.*, 1978). Later, the climate was more temperate and humid, causing the montmorillonite to degrade to kaolinite. The presence of in-situ hematite indicates a mean air temperature of at least 7° C and annual precipitation of 500 mm (Tarnocai and Schweger,

1991). Four paleosols developed on mountain tills in the Little Bear River section in the Mackenzie Mountains also indicate warmer-than-present climates during pre-Reid interglaciations (Tarnocai and Schweger, 1991)

Reid Glaciation

Landforms of the Reid glaciation are relatively well preserved, and consequently the Reid glacial limit has been fairly accurately determined (Fig.2-1 and 2-2)(Hughes *et al.*, 1969). Drumlins and flutings beyond the limit of the McConnell glaciation indicate that a similar pattern of flow prevailed during the Reid and McConnell glaciations, implying similar source areas. Unit 1 at Bradens Canyon indicates that climatic conditions were severe before the site was overrun by Reid ice.

Sediments deposited at the end of the Reid glaciation have not been extensively studied. The thick sequence of gravels at Pelly Farm Upstream was likely deposited as outwash during the initial stages of deglaciation. The presence of abundant Reid glaciolacustrine sediments along the lower reaches of the Pelly River imply that regional deglaciation could have been similar to that of the McConnell glaciation.

Post Reid Glaciation - Pre Koy-Yukon Thermal Event

The Ash Bend section on Stewart River has been mentioned previously in **REGIONAL QUATERNARY CONTEXT** since it contains the Sheep Creek tephra which provides a minimum date on the Reid Glaciation (Table 2 and 3) and the section also yields paleoclimatic information. The section has been described in detail by Hughes *et al.*, (1987), Clague *et al.*, (1992) and Schweger and Matthews (1992). A thick sequence of organic-rich silt containing wood, minor peat, mammal bones and the tephra infills a gully

incised into Reid glaciofluvial gravel. Analysis of pollen and plant and insect macrofossils below and above the tephra indicates an upward transition from boreal forest to arid tundra conditions. Based on the stratigraphic position of the boreal forest fossils below the Sheep Creek tephra, they could correspond to Isotope events 7.1 or 7.3 (C. Schweger, University of Alberta, personal communication, 1992) which have an age of 193 ka and 220 ka, respectively (Martinson *et al.*, 1987).

Koy-Yukon Thermal Event

During this interglaciation, Diversion Creek paleosols formed on deposits of the Reid glaciation (Tarnocai *et al.*, 1985; Smith *et al.*, 1986). Based on a comparison with soils forming at present, the Diversion Creek paleosols indicates a climate ~1° C warmer and slightly more humid than present (Tarnocai, 1990).

Other interglacial sites in Yukon indicate that conditions were warmer than present during the Koy-Yukon thermal event. At Ch'ijee's Bluff in northern Yukon, a complex of interstratified fluvial, lacustrine and organic deposits, which contain Old Crow tephra, now generally accepted to be 149 ka (Westgate, 1988), has provided abundant paleoecological information indicating that conditions were warmer during the Koy-Yukon thermal event than at present (Matthews *et al.*, 1990b).

Middle Wisconsinan Interstade

Several Middle Wisconsinan sites have been reported from central Yukon. The most important of these are the Mayo and Mayo Indian Village (MIV) sections (Matthews *et al.*, 1990a), the Ketza River site (Jackson and Harington, 1991) and the Granite Canyon section (reported here).

The Mayo and MIV sections are located along the Stewart River just downstream from Mayo (Matthews *et al.*, 1990a). Plant and insect macrofossils and pollen from these sections, supported by radiocarbon ages, allow a reconstruction of conditions from the Middle Wisconsinan to the beginning of the McConnell glaciation. Spruce forest existed in this area at 38,100±1330 yr BP (GSC-4554), but the vegetation had changed to xeric tundra by 29,600±300 yr BP (TO-292). Sedimentological studies indicate that Stewart River had changed from a wandering to a more braided planform over this time period (T. Giles, University of Alberta, personal communication, 1992). These data indicate climatic deterioration and, possibly, the advance of McConnell ice into the area.

The Ketza River site, located southwest of the Glenlyon map area, 30 km southeast of Ross River, has yielded abundant mammal remains that include *Mammuthus sp., Equus lambei, Bison sp. and Lepus sp* (Jackson and Harington, 1991). The mammal assemblage indicates a dry steppe grassland environment. The assemblage can be assigned to the Middle Wisconsinan on the basis of a radiocarbon age of 26,350±280 yr BP (TO-393). This age is also a maximum for the advance of McConnell ice into the area.

The Granite Canyon site (see **Middle Wisconsin Interstade**) confirms the presence of spruce forest in the region 36,000-37,000 yr BP as indicated by the Mayo Section.

McConnell Glaciation

Onset of the McConnell Glaciation

Little is known of the pattern of ice flow during the early phase of the McConnell glaciation. Precipitation patterns similar to present apparently controlled glacier growth (Jackson *et al.*, 1991). The present 600 mm isohyet

conforms closely with the source areas of the Cordilleran Ice Sheet (Fig. 2-14). Initiation likely followed the model of Davis and Mathews (1944): valley glaciers grew in the high areas of the Pelly, Selwyn and Cassiar mountains and then advanced down the main valleys (Jackson, 1989). This scenario has been confirmed by Plouffe (1989) who demonstrated with fabric data and pebble rock types that ice initially flowed out of the main ranges of the Pelly Mountains and subsequently flowed along the Tintina Trench. The distribution of erratics in the Glenlyon Range indicates that local cirque glaciers were small and made no significant contribution to the Selwyn Lobe (Ward and Jackson, 1992). Rather, the Selwyn Lobe flowed into the valleys of the Glenlyon Range, blocking the drainage and forming lakes (Section 12, Map 1787A). The limited size of the cirque glaciers in the Glenlyon Range is attributed to aridity. Present precipitation patterns show that the area recieves low precipitation (Fig. 2-14) and the situation was likely exacerbated during McConnell time. This situation apparently was exacerbated during the McConnell Glaciation since paleoclimatic information from Beringia, the large unglaciated land mass to the west of the study area, indicates that the period of the last glaciation was more arid than present (Hopkins1982). Other evidence for aridity is the occurrence of ventifacts (sand blasted clasts) beyond the limit of the McConnell Glaciation between a truncated paleosol on Reid deposits and loess deposited during McConnell deglaciation (Hughes *et al.* 1972; Tarnocai *et al.* 1985), and the fact that lakes adjacent to the ice sheet dried up (C. Schweger, University of Alberta, personal communication, 1992). Further coorberating evidence of aridity is given by a computer simulation model (Barnosky *et al.*, 1987)

The radiocarbon age of 26,350±280 yr BP (TO-393) from the Ketza River site is a maximum for glacier growth in the main ranges of the Pelly

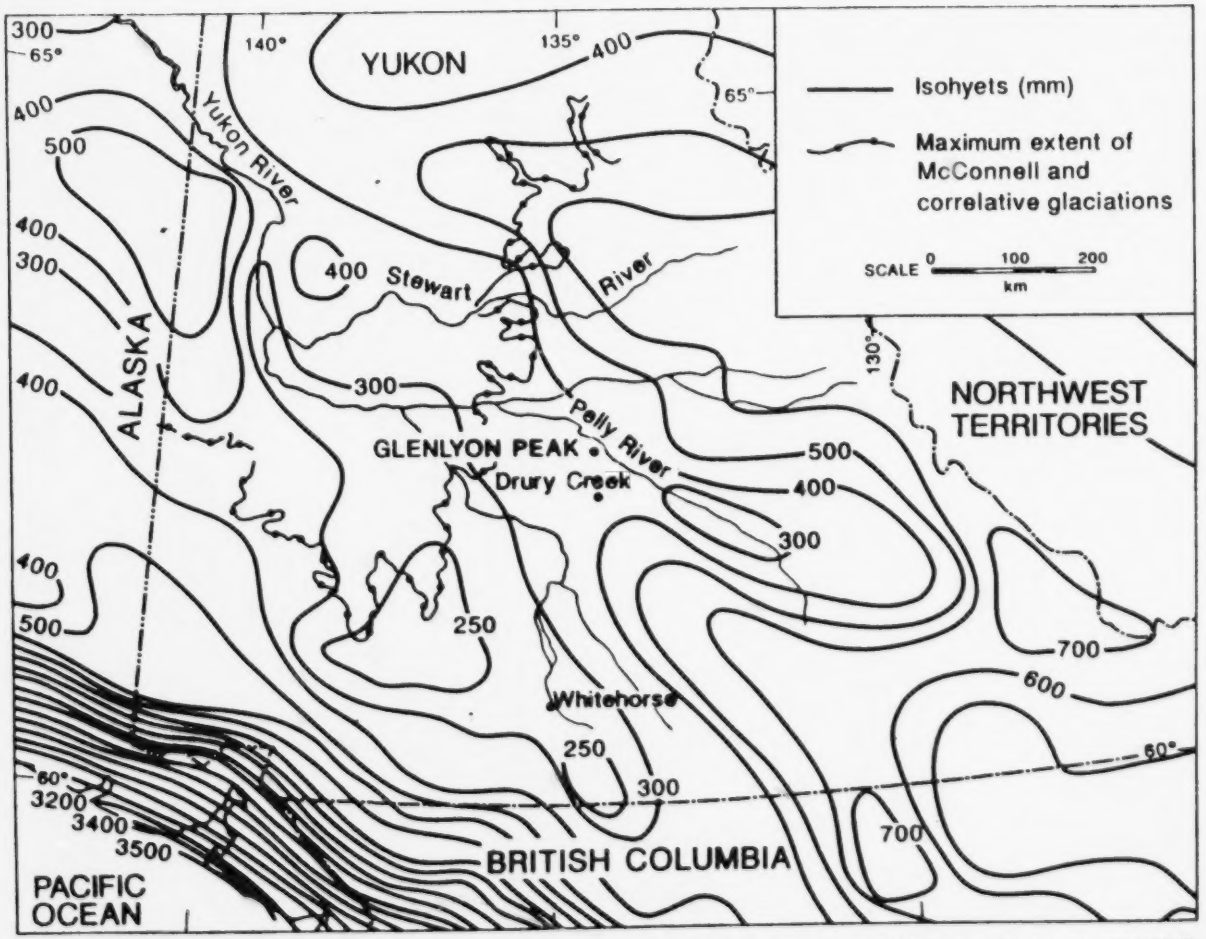


Fig. 2-14: Annual mean total precipitation for southern Yukon (modified from Wahl *et al.* 1987, Fig. 9.5; glacial limits from Hughes 1987, Fig. 7).

Mountains. As glaciers advanced down the main valleys, rivers likely changed from a wandering to a braided pattern. Section 26 indicates that the ancestral Pelly River aggraded its bed before McConnell ice overran the site. The two till sequence at Measured Section 29 (Map 1786A) demonstrates an oscillation of the Selwyn Lobe at some time during the McConnell glaciation, likely during advance.

Ice Flow at the McConnell Glaciation Maximum

Figure 2-7 shows ice flow directions and interaction of the Selwyn and Cassiar lobes at the maximum of the McConnell glaciation as determined from streamlined forms, glacial limits, pebble rock types and fabric data. Topography had a strong control on ice flow since topographic relief was approximately equal to or greater than the ice thickness. The ice sheet in this area is best described as a series of anastomosing ice streams (Jackson, 1989), with ice splitting around nunataks and subsequently recoalescing. The Selwyn Lobe flowed generally westward across the map area. Ice flowing along the Tintina Trench bifurcated and then coalesced around the Glenlyon Range (Fig. 2-7). Ice flowing along the Tintina Trench coalesced with ice from Tay, Menzie and Earn valleys. This caused some of the ice in the Tintina Trench to be deflected southwest into the main valleys of the Glenlyon Range, as indicated by the descending elevations of glacial limits in these valleys (Maps 1787A and 1789A). The Cassiar Lobe flowed generally northward into the area, mainly along the Yukon River and Frenchman Lake valleys, coalescing with the Selwyn Lobe.

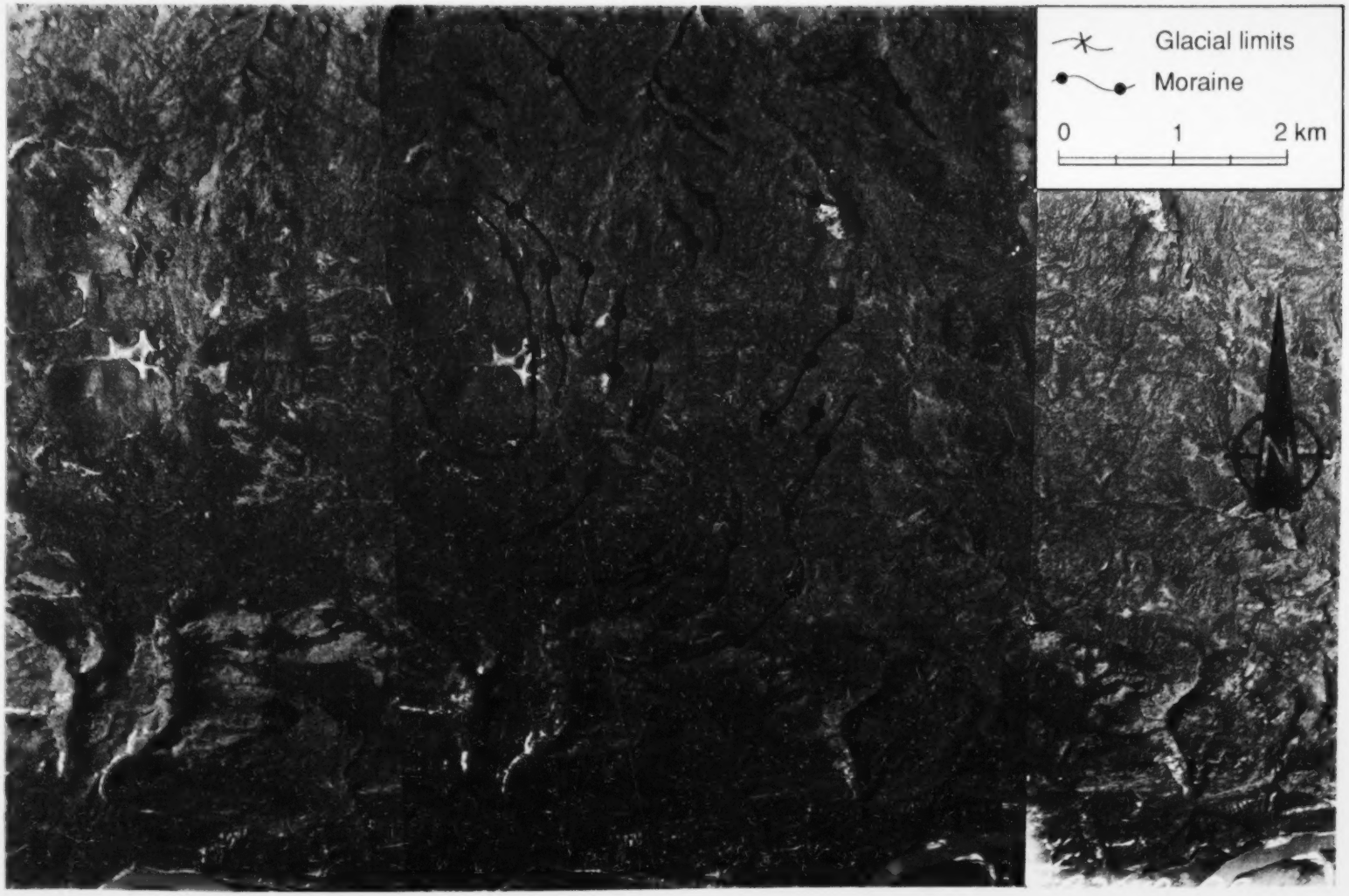
McConnell Deglaciation

After initial retreat, marked by recessional moraines within a few tens of kilometers of the McConnell glacial limit (Plate 2-16)(Maps 1786A, 1788A), the Selwyn Lobe stagnated and downwasted in place. Evidence for this includes ice-stagnation features to elevations of 1830 m in source cirques within the Pelly and Selwyn mountains (Jackson, 1989, in press; Jackson *et al.*, 1991). In addition, the sequence of lake deposits in tributary valleys shows that higher sites became ice free first, and that lake levels were controlled by downwasting ice in the main valley (Jackson, 1989; Jackson *et al.*, 1991).

Evidence for this type of tributary valley glaciolacustrine deposition during deglaciation is found in sections along Glenlyon (Section 6, Map 1789A), and Tay (Section 11, Map 1787A) rivers and Little Sheep Creek (Sections 12, Map 1787A). Airphoto interpretation indicates that glaciolacustrine sediments also are present along Felix and Jar creeks and at Drury Lake (Map 1789A), and along Harvey and Menzie creeks (Map 1787A). In the case of Menzie Creek no glaciolacustrine sediments were mapped but the presence of retrogressive thaw slides indicates the presence of fine grained sediments under glaciofluvial deposits. This evidence further corroborates the regional model of deglaciation of Jackson (1989).

The time of deglaciation of the Selwyn Lobe is not well known. A radiocarbon age of 12,590 ±120 yr BP (TO-931) on *Pisidium sp.* has been reported from the Tintina Trench adjacent to the Glenlyon Range, but possible hard water effects may render this age too old (Ward, 1989). The shells were obtained from a silty marl at the base of a kettle. Charcoal 90 cm above TO-931 gave an age of 8430 ± 60 yr BP (TO-1279). Another minimum deglaciation age is 9140 ±540 yr BP (AECV-484C) on willow wood from a paraglacial fan (Ward,

Plate 2-16: Recessional moraines on Pelmac Ridge (Map 1786A). National Air Photo Library A20110 - 97 and 98.


Glacial limits
Moraine
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1989). This age also yields a minimum for the establishment of upland vegetation.

The initiation of deglaciation in mountainous areas of Yukon and Alaska has been correlated with the Birch Zone (Hopkins, 1982). This is a pollen zone recorded throughout Beringia whose onset is marked by a rapid rise in *Betula* (birch) pollen. It records an abrupt climatic change from cold arid conditions to warmer and moister conditions (Ager, 1989; Anderson, 1985, 1988; Edwards and Dunwiddie, 1985; Hopkins, 1982; Ritchie, 1984, 1987). The inception of the birch zone is time transgressive across Beringia and occurs approximately 12,000 yr BP adjacent to the study area (Ritchie, 1987; Anderson, 1988). Basal ages to the north of the study area at Big Reid and Barlow lakes, within the Stewart River drainage, indicate that the begining of the Birch period preceded 9800 ±120 yr BP (GSC-2548) and 10100 ±90 yr BP (GSC-2538), respectively (McNeely, 1989, p. 50-51). It is likely that this period of climatic warming corresponds to the rapid decay of the Selwyn Lobe.

Pattern of Sedimentation During Deglaciation

The pattern of sedimentation was controlled by the style of regional deglaciation. The presence of abundant stagnant ice complexes formed several lake basins along Tintina Trench. Sedimentation processes were complex with material being deposited into lakes from melting ice, adjacent valleys and mass wasting from valley slopes. Basal tills are relatively rare with most diamictons representing deposition by sediment gravity flow. The presence of large thicknesses of highly disturbed sediments indicates sediments were deposited onto ice and subsequently slumped and failed. Undisturbed glaciolacustrine sediments were deposited either in more distal parts of the basin or after most of the ice had ablated. The abundance of

deformed sediment (Plate 2-5B), indicates that the style of deglaciation was by regional stagnation. A more orderly retreat of the ice sheet would have resulted in a simpler sequence of sediments, namely glacial diamicton overlain by outwash.

Holocene

Important Holocene events reflect the transition from glacial to nonglacial conditions, such as the re-establishment of vegetation in the map area and rivers cutting down to their present level. The re-establishment of vegetation has not been well studied in the map area. Only the age of 9140 ±)540 yr BP (AECV-484C) on willow wood from a paraglacial fan gives a minimum age for the establishment of upland vegetation (Ward, 1989). Detailed paleovegetational studies are lacking from lakes that have been cored. Limited palynological studies from Big Reid and Barrow lakes indicate vegetation dominated by birch, willow and cyperaceae at 9800 ±120 yr BP (GSC-2548) and 10100 ±90 yr BP (GSC-2538), respectively (McNeely, 1989, p. 50-51). After deglaciation, the present rivers began to cut down through thick, up to 125 m, deglacial valley fill sediments. A radiocarbon age from sample site 8 of 6570 +/-610 (AECV 483C) indicates that the Pelly River was ~25 m above its present level. The presence of the White River Tephra along the present floodplain of the Pelly and Yukon River indicates that Rivers had reached their present level by 1250 yr BP.

Another important Holocene event was the deposition of the White River Tephra at ca. 1250 BP during the cataclysmic eruption of Mount Bana near the Alaska-Yukon boundary (Lerbekmo *et al.*, 1975). It was observed over the southern the-quarters of the map area. Along the Pelly River it thinned rapidly

downstream of Safety Pin Bend and was not observed from the confluence of the Pelly and Macmillan Rivers to the Pelly Farm section.

APPLICATIONS

Engineering Applications and Geologic Hazards

Foundation conditions

Bedrock in the map area generally is excellent foundation material, although some Cretaceous volcanic rocks are incompetent (Plate 2-8). The presence or absence of permafrost is one of the most important controls on the suitability of surficial materials for foundations. The following discussion of foundation conditions is adapted from Jackson (in press).

Colluvial deposits are generally unsuitable for foundations. Coarse deposits, such as bouldery colluvial aprons (bCa), are commonly at or near the angle of repose and are thus metastable and subject to creep (Gardner, 1969). As well, the frequent occurrence of rock falls or avalanches may render them hazardous building sites. Colluvial aprons (Ca) are also subject to creep and may contain abundant organic material which can decompose and cause settling. Colluvial aprons with fine-grained matrixes may contain segregated ice.

The texture of alluvial deposits is highly variable, thus they have different attributes as foundation materials. Floodplains (Ap, Au) may be underlain by well drained gravel which is a good foundation material, or by organic rich-silt containing segregated ice lenses, which is unsuitable for foundations. Alluvial terraces (At) generally are well drained and are good building sites. Alluvial fans (Af) may be suitable for foundations depending on the texture of the sediment and the presence or absence of permafrost.

Glacial diamicton (Mv, Mb) is generally a good foundation material. It contains less segregated ice than finer material, although some slopes with northern aspects can have abundant permafrost. If segregated ice is present, moisture contents upon thawing are in excess of the liquid limit, and failure can occur on very low slopes.

Fine-grained glaciolacustrine deposits (Gp, Gv, Gb) commonly contain segregated ice lenses, making them highly prone to retrogressive thaw sliding and thermokarst formation. Care should be taken to ensure that areas of extensive permafrost in such sediments are avoided during development; areas with evidence of previous retrogressive thaw slides or containing thermokarst lakes should be avoided.

Organic deposits (O) are unsatisfactory foundation substrates because of their low bearing strength, compressibility, and the common occurrence of segregated ice.

Rock glaciers should be avoided for development because their slow, creep-like movement renders them unstable..

Granular materials

Bulk fill. Glacial diamicton (Mb,Mv) is found throughout the map area and can be easily exploited for low permeability bulk fill. It has been used extensively as fill and as surface material along the Robert Campbell Highway. As long as in-situ moisture contents are low it performs very well. Glaciolacustrine sediments can also be exploited for bulk fill, but the high moisture contents can cause segregated ice to form.

Sand and gravel. Sand and gravel are common throughout the map area. All glaciofluvial (G) and alluvial deposits (A) can be exploited for aggregate, but the quality will differ according to the texture and sorting of the specific deposit.

Present floodplains (Ap, Au) should be avoided since extraction will likely disrupt stream courses. Glaciofluvial deposits are widespread, but may be characterized by rapid lateral facies changes and may contain significant amounts of diamicton.

Natural hazards

Many natural process can pose hazards to human activity. The following discussion of natural hazards is modified from Jackson (in press) and Clague (1984).

Earthquakes

Glenlyon map area is located in an area of relatively low seismicity; most earthquakes are concentrated along Tintina Trench and other major structures in the area (Fig. 2-15). Since 1980 no earthquakes greater than M4 have occurred in the map area. But since the instrumented seismic record is short, there remains the possibility that large magnitude events could occur there.

Floods and debris flows

Flood hazards in the Pelly River basin have been examined as part of a larger study by The Inlands Waters Directorate (1983) of Environment Canada. Flooding can be caused by snowmelt runoff, rainstorm events, and ice jams. Snowmelt floods occur in early summer on Pelly and Yukon rivers and their larger tributaries. Pelly River at Pelly Crossing has a mean annual flood of 2430 m^3/s and a predicted 100 year flood of 5590 m^3/s. Rainstorm events have their greatest effect on smaller watersheds and generally produce floods in the summer. These floods usually occur in remote areas, thus there are little

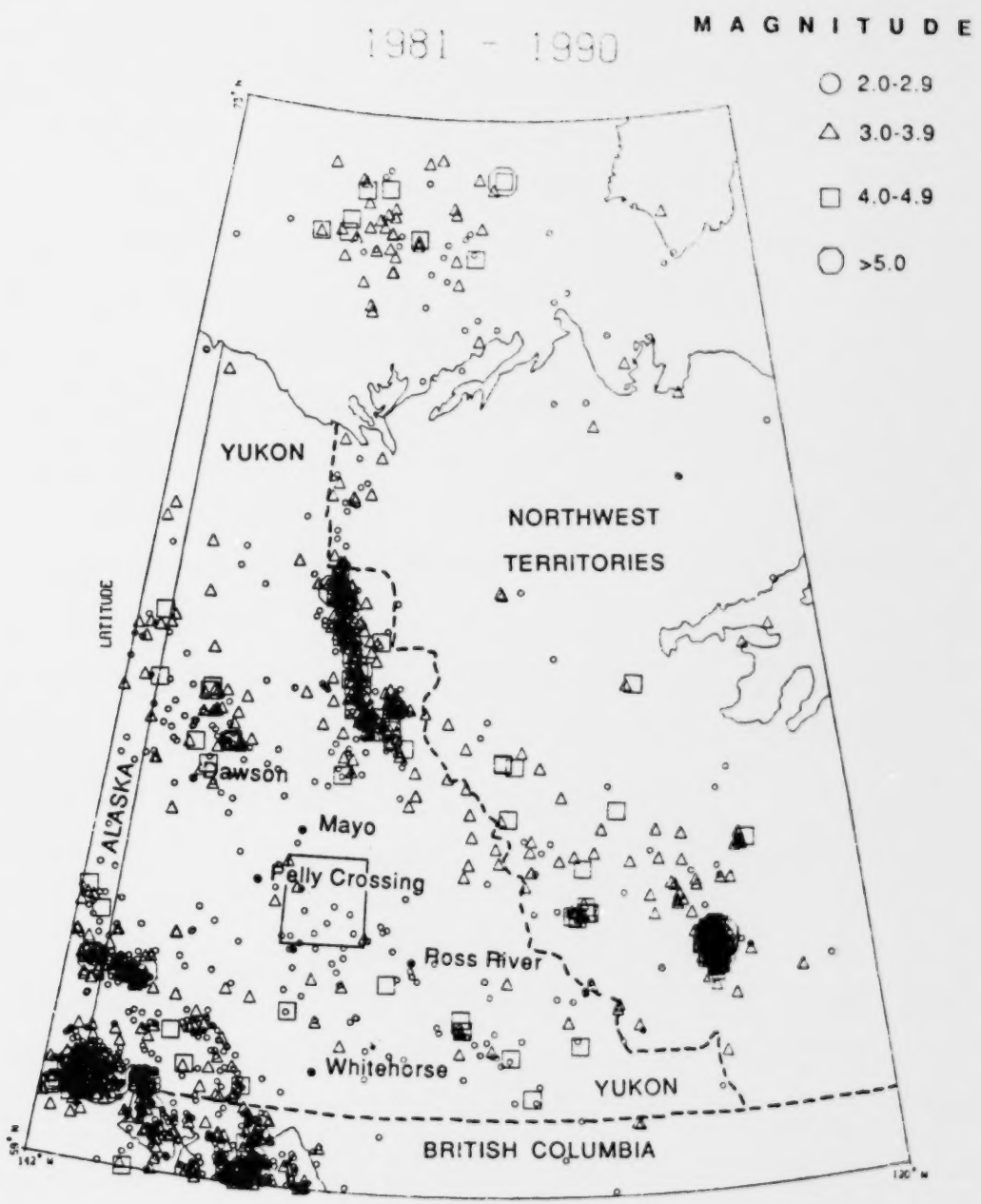

Figure 2-15: Earthquake epicenters for Yukon Territory and adjacent areas, 1981-1990. Provided by Pacific Geoscience Centre, Sidney, B.C.

data on their magnitude and frequency. They pose serious hazards in high-elevation or steeply sloping terrain where flooding or debris flows can occur rapidly with little warning. Ice jams can develop in any river or stream during break-up. Although they usually only affect short reaches, they are difficult to predict and can cause rapid increases in water level.

Hazards are greatest along the lowest parts of floodplains, but no part of the floodplain can be considered immune. Only alluvial terraces (At) and glaciofluvial terraces (Gt, Gp) are normally high enough to escape inundation. Active alluvial fans are prone to floods and debris flows, and the streams are capable of avulsion.

As development proceeds in the Glenlyon map area, the dangers of building on floodplains should be recognized and effective land use planning undertaken. The following planning guidelines have been recommend by Inland Waters Directorate (1983): (1) decide the level of protection required, for example the 1:100 or 1:200 year flood; (2) define a floodway, including the channel and those parts of the floodplain that must remain free of development; and (3) define which types of development to allow on other parts of the floodplain.

Landslides

Landslides have occurred throughout the map area in both bedrock and unconsolidated sediments (Plates 2-6, 2-8, 2-9). Although several large, catastrophic slides involving bedrock have been reported from the Pelly Mountains (Jackson and Isobe, 1990; Jackson, in press), only one large rockslide has been discovered in the map area, and this appears to be a slower, more complex type of failure (Plate 2-8). There is a possibility of recurrent failure at this site, thus development is not recommended.

Small rockfalls and debris avalanches are common, although they are restricted to alpine areas with steep slopes. Areas mapped as R-A and bCa should be avoided for development.

Most of the large landslides in the area are in unconsolidated material (Plate 2-9), and are likely the triggered by the degradation of permafrost. Most of these are in fine grained glacial glaciolacustrine sediment and till.. The largest failure in the map area is in fine-grained till. It occurred on a slope with a northern aspect and is similar to the well studied Surprise Rapids Slide in the Tay River map area (Ward *et al.*, 1992). The latter covers an area of more than 3 km^2 and is less than 100 years old. Initial dendrochronological work and airphoto examination suggest that the failure shown in Plate 2-9 formed in an equally brief period of time. Failure was initiated by some disturbance of the insulating organic cover, causing degradation of ground ice. Development on north-facing slopes underlain by fine-grained diamicton should be done with caution since similar failures could be triggered by disturbance of permafrost.

Smaller failures are common in glaciolacustrine sediments throughout the map area where fluvial erosion has exposed ice-rich permafrost (Plate 2-6). Development, such as road building, should be avoided in areas of glaciolacustrine sediments unless special precautions are taken.

Snow avalanching

Snow avalanching is one of the most widespread and destructive natural processes in the Canadian Cordillera (Evans and Gardner, 1989) and is potentially a serious hazard in the alpine part of the Glenlyon map area. Avalanche tracks are common in the alpine zone and should be avoided. Slopes prone to avalanching are mapped as R-A.

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CHAPTER 3 - LATE WISCONSINAN GLACIATION OF THE GLENLYON RANGE, PELLY MOUNTAINS, YUKON TERRITORY*

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INTRODUCTION

The Glenlyon Range, in southwest central Yukon, is the northwesternmost extension of the Pelly Mountains (Fig. 3-1). During the Late Wisconsinan, the Glenlyon Range was strongly affected by the Selwyn Lobe of the Cordilleran Ice Sheet. This ice generally advanced westward from its source in Selwyn Mountains (Fig. 3-1, inset) flowing around and into the Glenlyon Range, but leaving much of it as nunataks (Fig. 3-1)(Campbell 1967; Duk-Rodkin *et al.* 1986; Jackson *et al.* 1991; Ward and Jackson in press).

During mapping of the bedrock geology in Glenlyon map area (105L), Campbell (1967) concluded, on the basis of airphoto interpretation, that local valley glaciers in the Glenlyon Range did not coalesce with the Cordilleran Ice Sheet during the Late Wisconsinan McConnell Glaciation (Campbell 1967, p. 11). This is in contrast to the main ranges of the Pelly Mountains, farther to the southeast, where ice caps fed valley glaciers which extended into the main valleys and subsequently coalesced with the Cordilleran Ice Sheet (Jackson 1989; Plouffe 1989; Jackson *et al.* 1991). The explanation for these different glacial histories in adjacent ranges is the subject of this paper.

PHYSIOGRAPHY AND BEDROCK GEOLOGY

The main physiographic features in the study area are the Yukon Plateau, Tintina Trench and the Glenlyon Range of the Pelly Mountains (Fig. 3-1, inset). Tintina Trench is a long, linear valley that trends southeast-northwest across the Yukon Plateau. In the study area it contains the Pelly River. The Glenlyon Range contains abundant north-facing cirques with floor elevations of 1520-1680 m (Fig. 3-1). No glaciers are present in these cirques, although rock glaciers are common. The Glenlyon Range is dominated by a large

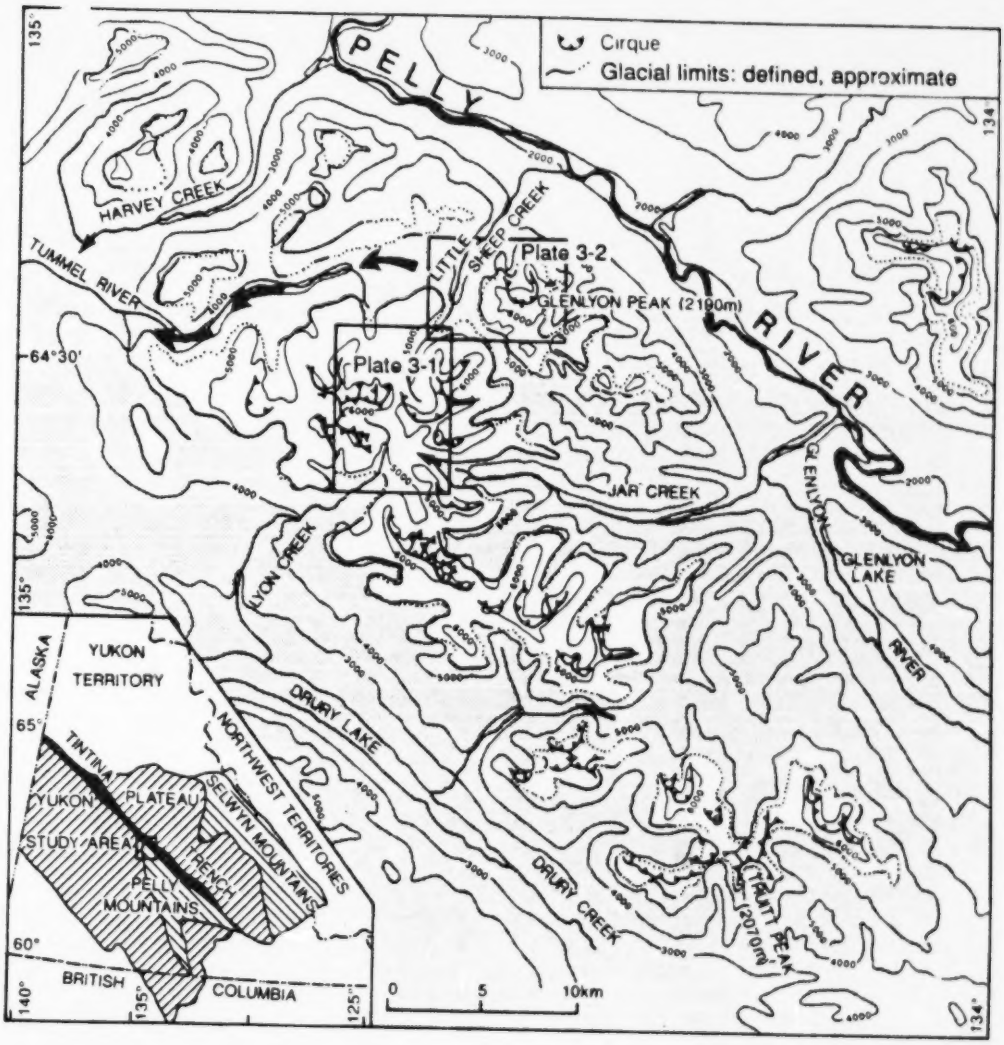


Fig. 3-1. Map of the Glenlyon Range showing local cirques and glacial limits. Stippled pattern highlights area covered by the Selwyn Lobe. Arrows indicate meltwater flow during deglaciation. Locations of Plates 3-1 and 3-2 are indicated. Topographic contours are in feet. Inset map shows physiographic regions mentioned in the text and the location of the study area.

granitic (granodiorite and monzonite) pluton with associated roof pendants of metamorphic rocks of variable grade (Campbell 1967).

Two other rock types, located north of Tintina Trench, are important erratic indicators of the Cordilleran Ice Sheet. One, the Crystal Peak Formation, is a chert pebble conglomerate (Campbell 1967; Gordey and Irwin 1987), and the other, the South Fork Volcanics, is a densely welded crystal tuff (Gordey and Irwin 1987; Gordey 1988). The only way that these two distinctive rock types, as well as other sedimentary and volcanic clasts, could have been transported into the Glenlyon Range is by the Cordilleran Ice Sheet flowing southwest across Tintina Trench.

STRATIGRAPHIC FRAMEWORK

The moraines and surfaces discussed are placed into the standard Quaternary sequence of central Yukon (Bostock 1966; Hughes *et al.* 1969). This glacial sequence, from youngest to oldest, consists of the McConnell, Reid, and pre-Reid glaciations. The McConnell Glaciation is Late Wisconsinan, and the Reid Glaciation is now considered to be Illinoian (Hughes 1987).

During the McConnell deglaciation, the Selwyn Lobe stagnated and downwasted in place, indicating a rapid rise in the firn line (Jackson 1989). Evidence for this rapid rise is provided by ice stagnation features that extend into cirques and by lake deposits that descend in elevation down valley systems (Jackson 1989; Jackson *et al.* 1991). Lakes could only have been dammed in higher valleys if ice in lower valleys blocked the drainage; this indicates that the higher valleys were deglaciated first.

METHODS

In conjunction with regional mapping, detailed airphoto analysis was undertaken to determine the glacial limits and the nature of interaction between the Selwyn Lobe and local ice from the Glenlyon Range. Fieldwork was carried out along Little Sheep Creek and in the area near Glenlyon Peak (Fig. 3-1). Areas near the headwaters of Jar, Little Sheep and Lyon creeks and a small unnamed valley, hereafter referred to as the cirque valley, are described below.

RESULTS AND INTERPRETATIONS

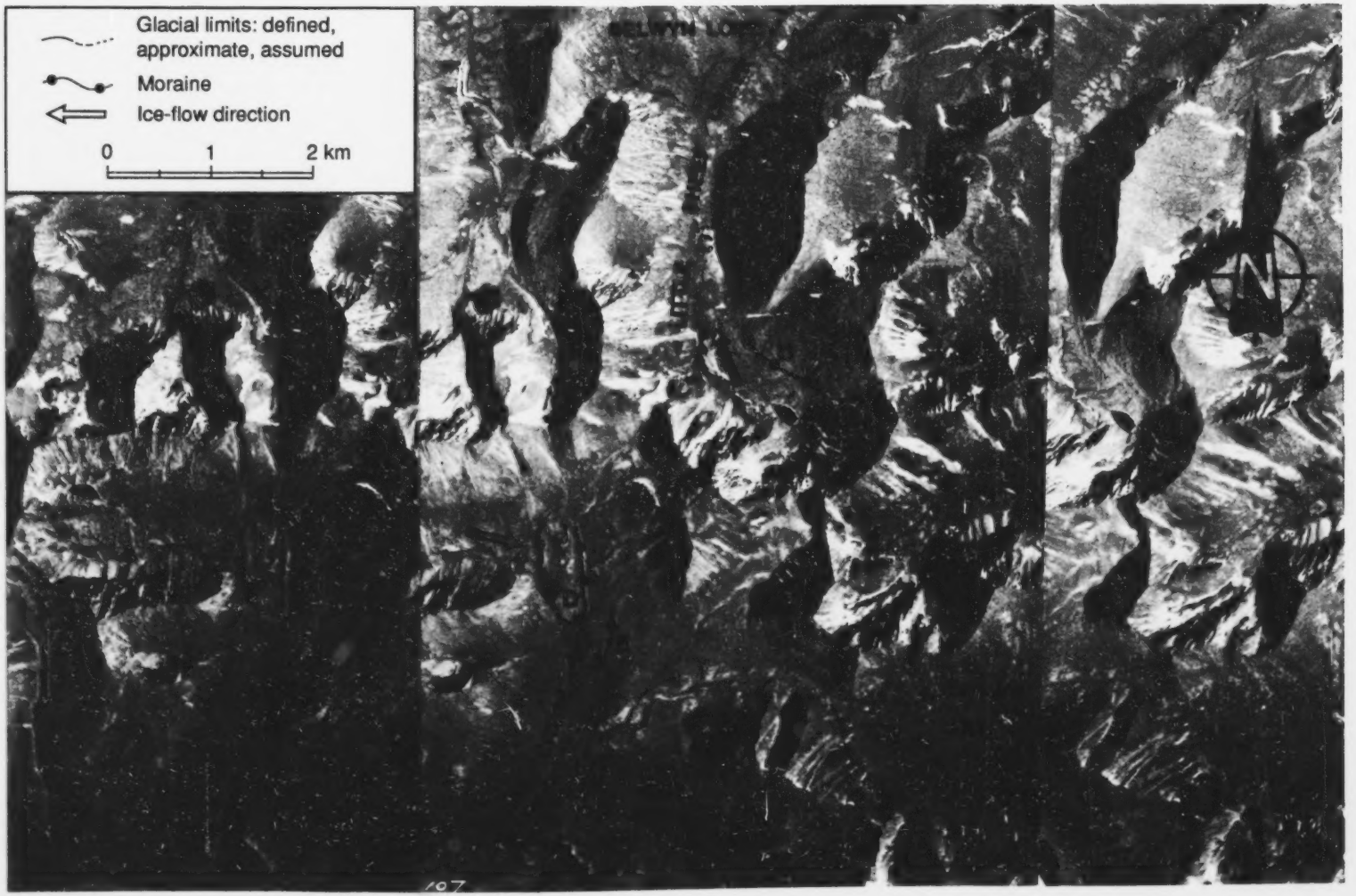
Regional Airphoto Analysis

The mapped glacial limits (Fig. 3-1) in general agree well with those of Campbell (1967) and Duk-Rodkin *et al.* (1986), who used them to reconstruct the Selwyn Lobe. Not all areas of the Glenlyon Range have well defined glacial limits. Ice-marginal features are most poorly developed on north facing slopes (see Jar Creek, Plate 3-1) and at high elevations. Most cirques have northern aspects, and thus moraines marking the extent of local ice are generally either nonexistent or poorly preserved, although there are exceptions.

Jar Creek

The headwaters of Jar Creek are on the east side of the Glenlyon Range, south of Glenlyon Peak (Fig. 3-1 and the eastern part of Plate 3-1). Lakes on the floors of two small cirques in this area are ponded behind moraines. One of these lakes is marked A in Plate 3-1, and the second lake (not shown), occurs 1.5 km to the east in an adjacent cirque. The moraines

Plate 3-1: Aerial photograph of the headwaters of Little Sheep, Lyon and Jar creeks (see Fig. 3-1 for location). Letters refer to the following features: A, lake dammed by a moraine; B, lateral moraine; C, approximate maximum extent of a local glacier from Little Sheep Creek; D and E, moraines from Lyon Creek; and F, moraine marking the maximum extent of the Selwyn Lobe. National Airphoto Library A20059 - 106,107 and 108.


Glacial limits: defined, approximate, assumed
Moraine
Ice-flow direction
0
1
2 km
N

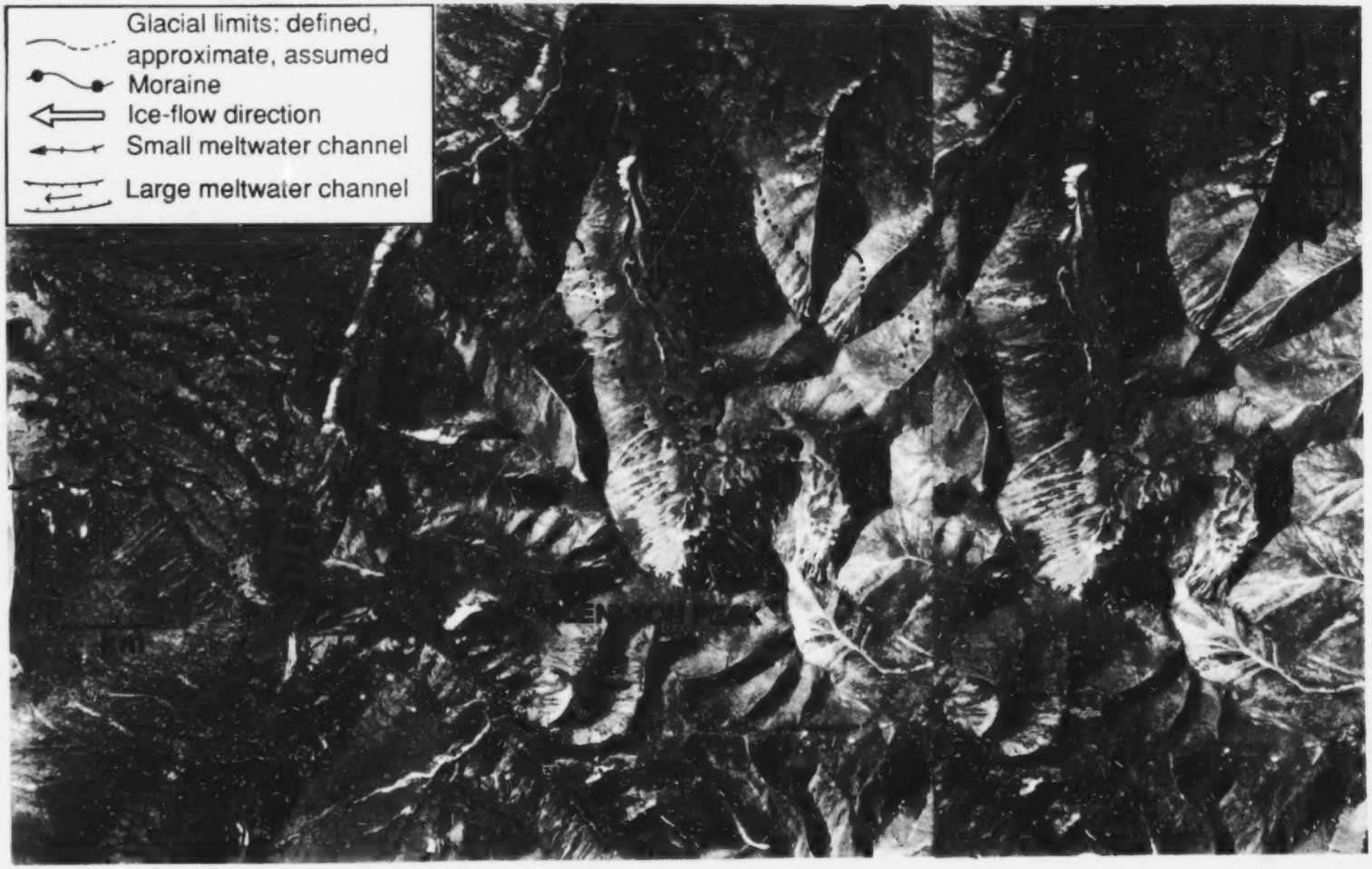
impounding these lakes are interpreted to have been built by the Selwyn Lobe. The moraines could also be the products of a late glacial advance of local ice, but since they are coincident with other ice-marginal features of the Selwyn Lobe (Plate 3-1), this is considered unlikely. The fact that ice of the Selwyn Lobe did not flow into these cirques suggests that cirque glaciers, 500-700 m long, were present. This indicates that some local glaciers did coalesce with the Selwyn Lobe, but they did not contribute significantly to its volume.

Little Sheep Creek

The headwaters of Little Sheep Creek are 3 - 4 km north of Jar Creek (Fig. 3-1, Plate 3-1). On the eastern side of the valley is a weakly preserved lateral moraine with a upper limit of approximately 1710 m (B in Plate 3-1). No well-defined end moraines are present, but the maximum extent of the local glacier in Little Sheep Creek Valley is assumed to coincide with the down-valley margin of a thick surficial blanket of probable glacial deposits (C in Plate 3-1), indicating that this glacier advanced approximately 3 km from the cirque headwall. This advance likely represents the McConnell Glaciation, but in the absence of any age controls, it could also represent an older glaciation.

Thick glaciolacustrine deposits, marked on airphotos by lighter tones and dendritic drainage channels, are present between point C and the approximate limit of the Selwyn Lobe, approximately 4 km farther downvalley (Plate 3-1 and the southwest corner of Plate 3-2). Regardless of the age of the local moraine, this configuration indicates that local ice in Little Sheep Creek Valley did not coalesce with the Selwyn Lobe.

Plate 3-2: Aerial photograph of Glenlyon Peak, cirque valley, and Little Sheep Creek (see Fig. 3-1 for location). Letters refer to the following features: LSC #1 and LSC #2, sections along Little Sheep Creek #1 and 2; VM, Valley Mouth Section; Cor, moraine representing deposition by the Selwyn Lobe; Loc, moraine from the local cirque. National Airphoto Library A20059 - 114 and 115.


Glacial limits: defined, approximate, assumed
Moraine
Ice-flow direction
Small meltwater channel
Large meltwater channel

Lyon Creek

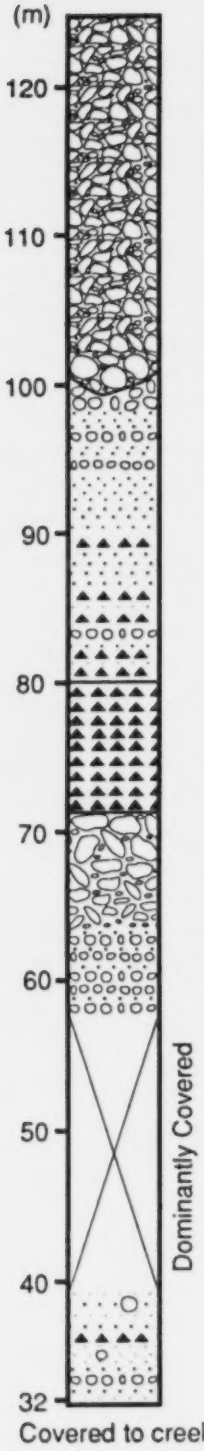
Well preserved moraines which formed during a cirque advance occur in the headwaters of Lyon Creek, just across the divide from Jar Creek (Plate 3-1). A series of moraines extend eastward and then southward 3 - 3.5 km from the cirque headwall (D and E in Plate 3-1). The three freshest moraines have upper elevations of ca. 1710 - 1740 m while the outermost moraine is at approximately 1680 m. Based on airphoto interpretation, the outermost moraine (E) appears to be less well defined and more subdued than the inner three. The moraines marked D are interpreted as representing the McConnell advance. However, interpretation of the outer moraine (E) is problematic. This moraine could be the McConnell terminal moraine or it may belong to the Reid glaciation. The maximum extent of the Selwyn Lobe is defined by the moraine marked F in Plate 3-1 Ice from Lyon Creek did not coalesce with the Selwyn Lobe during the McConnell glaciation.

Stratigraphy of Exposures

Little Sheep Creek #1 exposure (LSC #1 on Plate 3-2) provides important information on the Late Wisconsinan glacial history of the area. The units in this section are described in Fig. 3-2.

Unit 1 coarsens upward from sands at the base to coarse, chaotic gravels at the top. The sands contain abundant dropstones and are interstratified with infrequent gravels and diamictons. The upper portion of the unit is dominated by gravels which become coarser and more poorly sorted upwards. Clast rock types throughout are dominated by granites with 5-10% sedimentary and volcanic clasts.

Unit 1 was deposited in a glaciolacustrine environment. It is not clear whether this lake became filled with sediment before the deposition of unit 2,



Unit 4 - Gravel
Lower contact sharp, erosive and channelized; associated with clasts up to 1m. Subrounded boulders and cobbles throughout. Moderately stratified, marked by changes in clast size. Matrix dominantly coarse sand.

Unit 3 - Interbedded Gravel, Sand and Diamicton
Lower contact gradational. Diamictons dominate in lower 5m; normally graded, coarse to medium sands in the middle portion; pebble and cobble gravels in upper 2m.

Unit 2 - Diamicton
Lower contact sharp, distinct and horizontal. Matrix massive and sandy. Clasts striated and ~20%.

Unit 1 - Sand and Gravel
Coarsens upward from dominantly sand at the base to dominantly gravel at the top. Lowest exposure consists of interbedded well stratified, fine to very coarse sands, diamicton with striated clasts, and poorly sorted gravels; abundant dropstones present. Spotty exposures in covered interval indicate transition between upper and lower exposures. Upper exposure is dominantly coarse gravel that coarsens and becomes more poorly sorted upwards.

Figure 3-2: Stratigraphic section Little Sheep Creek #1. Location shown in Plate 3-2.

however, the lake formed when ice in Tintina Trench blocked the mouth of Little Sheep Creek. The coarsening-upward nature of the unit likely indicates a combination of both increased proximity of source and shallowing with time.

Unit 2 is a diamicton with a sharp lower contact. The matrix, which appears to be massive, is 57% sand, 28% silt and 15% clay. Clasts up to 1m in diameter constitute ~20% of the unit. Rock types are dominated by granites, with ~10% erratics, including clasts of the South Fork Volcanics and Crystal Peak Formation (S. Gordey, personal communication, 1988). These erratics suggest that unit 2 is a glacial diamicton deposited by the Selwyn Lobe.

Unit 3 consists of interstratified gravels, sands and diamictons. The lower contact is gradational with the lower portion of the unit dominated by diamictons. Well stratified, normally graded sands constitute the rest of the unit except for the uppermost 2m which consists of pebble and cobble gravels.

Unit 3 is interpreted to be subaqueous sediment gravity flow deposits on the basis of its interbedded nature, the well stratified, normally graded sands, and the absence of crossbedding and cut-and-fill structures. The lake in which these sediments were deposited likely was dammed by a tongue of the Selwyn Lobe which persisted in Tintina Trench after Little Sheep Creek had been deglaciated. This lake was relatively long-lived, as indicated by the large meltwater channel that fed water over the present drainage divide into Tummel River (Plate 3-2).

Unit 4 comprises weakly stratified, coarse, boulder to cobble, gravels. It has a sharp, erosive lower contact with associated clasts up to 1m in diameter. Unit 4 is interpreted as being deposited in a glaciofluvial environment during and subsequent to the draining of the lake indicated by unit 3.

Little Sheep Creek #2 and the valley-mouth section (LSC #2 and VM in Plate 3-2) also contain sandy diamicton units (51% sand, 29% silt, 20% clay;

51% sand, 32% silt, 17% clay; respectively). These diamictons contain 10-15% erratics, including clasts of the South Fork Volcanics and the Crystal Peak Formation (S. Gordey, Geological Survey of Canada, personal communication, 1988). Diamictons containing Cordilleran Ice Sheet indicator erratics at LSC#1,#2 and VM sections provide evidence that this portion of Little Sheep Creek Valley was initially inundated by the Selwyn Lobe and not local glaciers. This is corroborated by the lake sediments of unit 1 at LSC#1 which indicate that ice in Tintina Trench blocked the mouth of Little Sheep Creek before the till of unit 2 was deposited. The existence of a lake during deglaciation, recorded by unit 3, indicates that ice persisted in Tintina Trench after Little Sheep Creek was deglaciated, providing support for the model of regional deglaciation of Jackson (1989).

Distribution of Erratics In The Cirque Valley

The distribution of sedimentary and volcanic erratics in the cirque valley also indicates no contribution of ice from the Glenlyon Range to the Selwyn Lobe. From the Valley Mouth section to the moraine marked Cor in Plate 3-2, sedimentary and volcanic erratics were found exposed at the surface; some of these are South Fork and Crystal Peak erratics (S. Gordey, personal communication, 1988). Between the moraine marked Cor and the one marked Loc in Plate 3-2, the abundance of erratics declines abruptly to zero. The moraine at Loc (upper elevation ca. 1710 m) consists entirely of angular, local granitic clasts >2 mm(Plate 3-3).

These data indicate that no local ice blocked the advance of the Selwyn Lobe into this valley. This advance has not been dated, but based on correlations with other geomorphic features, the low, poorly preserved moraine

Plate 3-3: Moraine marking the limit of local ice from the cirque valley; the highest portion of moraine is ~100 m above valley floor. View is to the southeast from the moraine marked Cor on Plate 3-2.

marked Cor in Plate 3-2 is interpreted as representing the maximum extent of the Selwyn Lobe during the McConnell Glaciation (Figs 3-1, Plate 3-2). Although degraded (Plate 3-3), the moraine marked Loc is thought to delineate the maximum extent of ice from this cirque during the McConnell Glaciation. If these correlations are wrong and these moraines were deposited during an older glaciation, the initial conclusion still holds: the cirque did not contribute ice to the Selwyn Lobe during McConnell Glaciation.

DISCUSSION

The evidence given above indicates that, as originally suggested by Campbell (1967), there was little contribution of ice to the Selwyn Lobe from local glaciers in the Glenlyon Range during the McConnell Glaciation. Aridity probably accounts for the limited extent of these glaciers; there was insufficient precipitation to allow extensive glacier growth in the Glenlyon Range. Present precipitation patterns indicate that the Coast and St. Elias mountains remove much of the moisture from incoming Pacific air (Fig. 3-3). This situation apparently was exacerbated during the McConnell Glaciation since paleoclimatic information from Beringia, the large unglaciated land mass to the west of the study area, indicates that the period of the last glaciation was more arid than present (Hopkins1982). Other evidence for aridity is the occurrence of ventifacts (sand blasted clasts) beyond the limit of the McConnell Glaciation between a truncated paleosol on Reid deposits and loess deposited during McConnell deglaciation (Hughes *et al.* 1972; Tarnocai *et al.* 1985), and the fact that lakes adjacent to the ice sheet dried up (C. Schweger, University of Alberta, personal communication, 1992). Further coorberating evidence of aridity is given by a computer simulation model (Barnosky *et al.*, 1987).

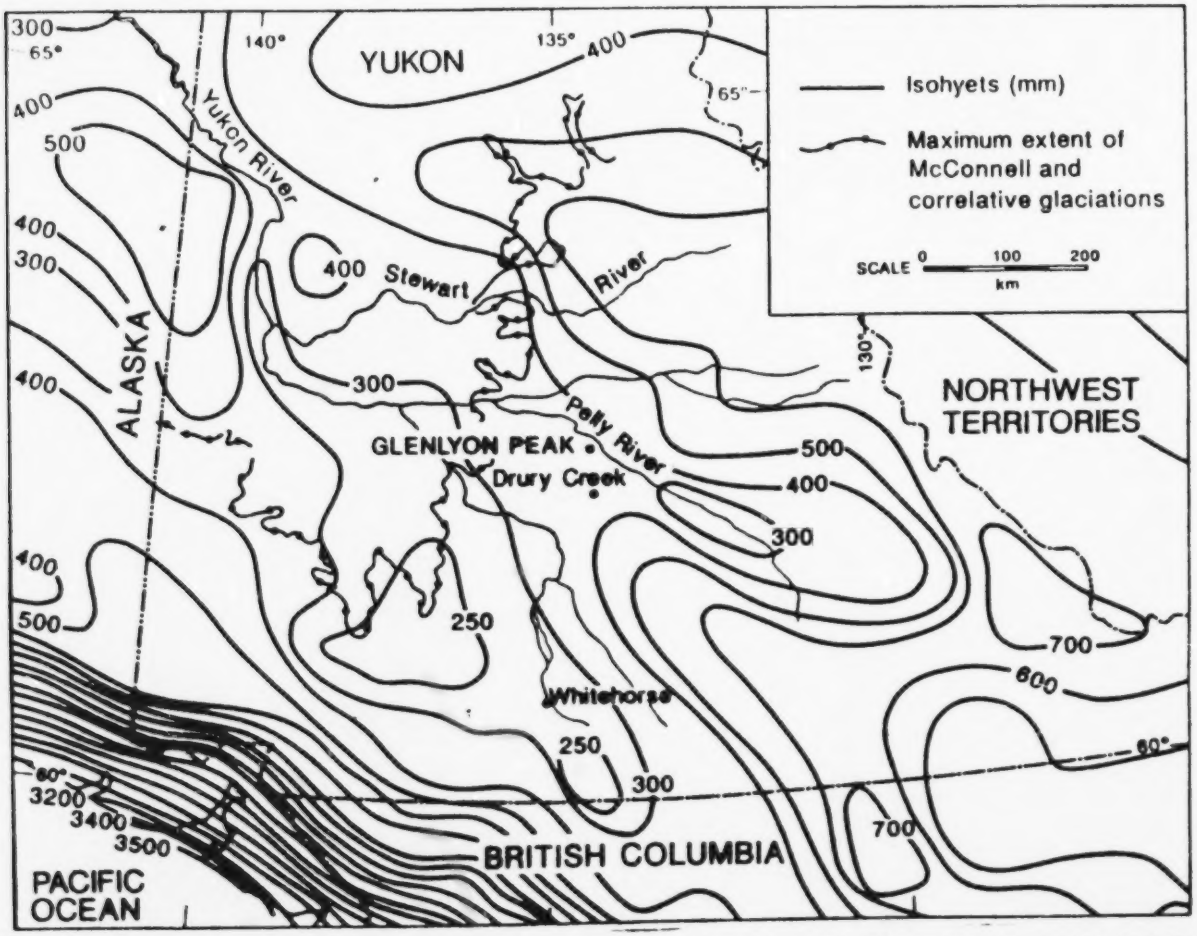


Fig. 3-3: Annual mean total precipitation for southern Yukon (modified from Wahl *et al.* 1987, Fig. 9.5; glacial limits from Hughes 1987, Fig. 7).

The limited extent of glaciers in the Glenlyon Range can be reconciled with the work of Jackson (1989) and Plouffe (1989), indicating much more extensive ice in the main ranges of the Pelly Mountains, by considering the present distribution of precipitation (Fig. 3-3). Although absolute precipitation values would likely have been different during McConnell time (cf. Barnosky *et al.*, 1987), the contemporary 600 mm isohyet is known to correspond closely to the divide areas of the northern portion of the last Cordilleran Ice Sheet (Jackson *et al.* 1991). The main ranges of the Pelly Mountains, which are comparable to the Glenlyon Range in elevation, are within this isohyet, whereas the Glenlyon Range receives <400 mm of mean annual precipitation (Wahl *et al.* 1987). The occurrence of extensive ice in the main ranges of the Pelly Mountains and very limited ice in the Glenlyon Range indicates a very steep climatic gradient over a distance of 100 - 200 km, likely steeper than that which separates the two areas now.

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CHAPTER 4 - DEGLACIAL VALLEY FILL SEDIMENTATION , PELLY RIVER, YUKON TERRITORY, CANADA*

*A version of this chapter will be submitted for publication to Boreas, Ward, B. C. and Rutter, N. W. R.

INTRODUCTION

Many glaciated valleys contain thick sediments deposited during deglaciation. The style of deglacial valley fill sedimentation can be divided into two end members based on the type of deglaciation: 1) where deglaciation is gradual with an orderly retreat of the ice front; and 2) where deglaciation is rapid and the ice sheet melts by regional stagnation.

Gradual deglaciation has been described from various parts of the world: The Canadian Rocky Mountains associated with the margin of the Cordilleran Ice Sheet (Rutter, 1972a and b) and Norway and Sweden, associated with the Scandinavian Ice Sheet (Bergersen and Garnes, 1983; Lundqvist, 1983; Sollid and Reite, 1983). Commonly the sequence consists of till overlain by glaciofluvial outwash gravels.

During regional stagnation there is no orderly retreat of the ice front and abundant glacial lakes commonly form, resulting in thick sequences of glaciolacustrine sediment (Fulton, 1965, 1967). In some cases deposition occurred in supraglacial lakes or in close association with stagnant ice, resulting in complex sediments which have been deformed by the melting of supporting ice (Shaw and Archer, 1979; Eyles *et al.*, 1987; Fitzsimons, 1992). Regional stagnation was typical of Late Wisconsinan deglaciation throughout the Interior System of the Canadian Cordillera (Fulton, 1991; Jackson *et al.*, 1991), and is characterized by thick glaciolacustrine sediments, some disrupted by slumping and faulting (Fulton, 1965, 1967; Shaw, 1975, 1977; Shaw & Archer, 1978, 1979; Fulton & Achard, 1985; Eyles *et al.*, 1987; Eyles & Clague, 1991; Ryder *et al.*, 1991) Many of these studies indicate that at least some of the deposition was in supraglacial lakes.

The most detailed studies of supraglacial sedimentation are provided by Shaw and Archer (1978, 1979), Eyles *et al.* (1987), Shaw (1988) and Eyles and Clague (1991). Eyles *et al.* (1987) interpret a sequence dominated by normally graded gravel and sand with rare diamicton and mud as being deposited by sediment gravity flow. The occurrence of extensive deformation in the form of faulting, folding and injection of clastic dikes was taken to indicate that the sediments were deposited above ice and they propose a depositional model for supraglacial lakes. Shaw (1988) criticized this model because it did not incorporate studies of supraglacial sedimentation from the Okanagan and South Thompson valleys where sedimentation was finer grained. He proposed an alternate model in which over time energy levels would decrease and the coarse sediments would be covered by silts and clays. Further work by Eyles and Clague (1991) confirmed the presence of laterally continuous finer grained sediment that was deposited supraglacially.

The purpose of this paper is to further document the pattern, character and origin of the second end member of deglacial valley fill, where sedimentation occurred in supraglacial lakes. The Pelly River in central Yukon is a region where deglaciation was by regional stagnation and few studies have been undertaken.

PREVIOUS WORK

Little detailed work on the sedimentology of deglacial sediments have been published from Yukon. Dawson (1889) was the first to report the presence of complex sequences of glacial sediments , some contorted, along the Pelly River. Campbell (1967) did the most detailed work on the glacial history of the area, defining upper limits of glaciation, patterns of meltwater flow, and the distribution of some deglacial lakes.

REGIONAL SETTING

Physiography

The study area contains three physiographic regions of Yukon: the Tintina Trench, the Yukon Plateaus, and the Glenlyon Range of the Kaska Mountains (Fig. 4-1)(Mathews, 1986). The Tintina Trench, a long, linear, structurally controlled valley, trends SE-NW across central Yukon, following the trace of the Tintina Fault. In the study area Tintina Trench is up to 4 km wide with elevations in the range of 600 m asl. The Yukon Plateaus has moderate relief, a variable topography and occupies a large area in central Yukon. Adjacent to the study area it is generally smoothly undulatory, with most elevations between 600 and 1200 m. The Yukon Plateaus region also contains several upland areas, such as the Macmillan Range (Fig. 4-1) with elevations up to 1800 m. The Glenlyon Range has high relief with most summits in excess of 1980 m.

The Pelly River flows northwest across central Yukon and is part of the Yukon River drainage system. For the first 200 km it follows the Tintina Trench until the area of The Detour (Fig. 4-1), where it leaves Tintina Trench and flows generally to the west. It is subsequently joined by the Macmillan River and eventually flows into the Yukon River.

Quaternary Context

During the Late Wisconsinan McConnell glaciation the area was affected by the Selwyn Lobe of the Cordilleran Ice Sheet (Campbell, 1967). This ice generally flowed westward from its source in the Selwyn Mountains, inundating the area but leaving many of the peaks in the Glenlyon Range as nunataks (Fig. 4-1). The maximum westward extent of the Selwyn Lobe in the Pelly Valley was at Granite Canyon (Fig. 4-1). The approximate elevation of

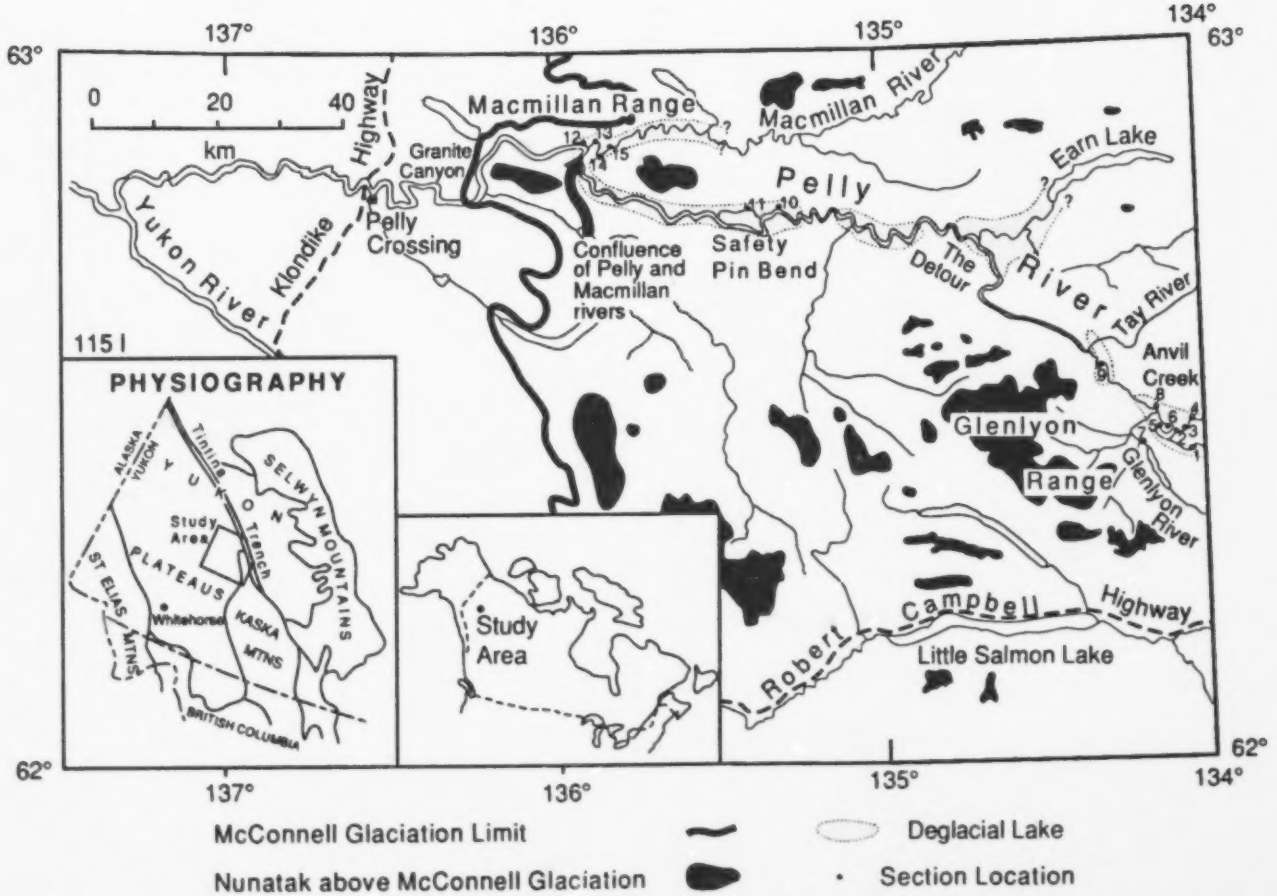


Figure 4-1: Location map of the study area with glacial limit, nunataks, deglacial lakes and section locations indicated. Inset map shows major physiographic regions of Yukon Territory (After Matthews, 1986).

the glacial limits above river level are 500, 1000 and 1200 m at the confluence of the Pelly and Macmillan rivers, at The Detour and at Anvil Creek, respectively. Previously deposited glacial material was an important source of sediment for glacial lakes, and thus, the limits height above the river had an affect on sediment availability and is discussed later.

Deglaciation was rapid with the ice sheet mostly melting from the surface, and the highest valleys became ice free first (Jackson *et al.,* 1991). With ice in the lower valleys blocking drainage, glacial lakes formed in the higher valleys. In the main valleys, such as the Pelly River valley, glacial lakes also formed, dammed by stagnant ice, likely aided by isostatic depression; Hughes (1990) reports differential isostatic uplift of 2.28 m/km for an area in southern Yukon, and similar values could be expected here. At Granite Canyon a dam of outwash and stagnant ice blocked the Pelly River. The resulting lake extended up the Pelly River to at least Safety Pin Bend and up the Macmillan River at least 20 km (Fig. 4-1). There is evidence for local, minor surge readvances during overall deglaciation (Jackson *et al.*, 1991, Plouffe and Jackson, 1992).

METHODS

More than 30 sections were described and measured along the Pelly River and adjacent creeks over a distance of 100 km from the area of Anvil Creek to the confluence of the Pelly and Macmillan rivers (Fig 4-1). Elevation of the sections was established by altimetry tied into bench marks and spot elevations from 1:50 000 maps. Elevations are estimated to have an accuracy of $\pm$ 2-3 m, except at section 7, where the elevation was determined by the average river gradient and is estimated to have an error of $\pm$ 10 m. Sections were subdivided into units for convenience of description, often with each unit representing a broad depositional environment.

The approximate aerial distribution of deglacial lakes in the study area were determined by airphoto interpretation and the distribution of sediments (Fig. 4-1). Areas with a surface expression of interlocking crevasse fill ridges and esker like features are interpreted as representing subaerially exposed stagnant ice which likely acted as dams for lakes.

For diamictons the trend and plunge of the a-axis of elongate pebbles were measured, and for gravels the dip and dip direction of a-b planes were measured. Mean orientations and strengths of alignment were calculated by the eigenvector methods of Mark (1973). The principle eigenvector (V1) gives the mean orientation of the data set. The eigenvalues (S1, S2, S3) give a measure of the strength and style of the distribution of the data set. If S1, the principle eigenvalue, is much greater than the other two then it indicates a strong clustering. If S1 and S2 are approximately equal and greater than the third then the distribution is a girdle. If all the eigenvalues are approximately the same then the distribution is random.

Grain size was determined by hydrometer and sieving. Determinations were from the <2 mm fraction from the matrixes of diamictons and gravels, and bulk samples from the other sediments types

FACIES

Sediments were grouped into eight facies (Table 4-1) on the basis of objective criteria: grain size (Fig. 4-2), sedimentary structures (Plate 4-1), clast fabric (Fig 4-3, Table 4-2), and presence or absence of deformation features (c.f. Walker, 1984). Because of the regional nature of this study, many of these facies contain a wide range of sediment types and structures. Where possible, the main diagnostic characteristic of each facies is included in the facies name. Based on these criteria, a depositional environment is proposed for each

Facies	Grain size and structures	Interpretation
A-Massive Diamicton	Pebbles to large boulders, 25-35%, commonly striated and faceted; silty-sand matrix (Fig. 4-2), dense and massive (Plate 4-1A); strongly oriented pebble fabrics (Fig. 4-3, Table 4-2); rare, discontinuous sand and gravel lenses.	Basal till
B-Stratified Diamicton	Pebbles to boulders, 5-30%, striations; silty-sand matrix (Fig. 4-2), stratified on the 2 to 150 cm scale by layers of sorted sediment (Plate 4-1B), changes in grain size, and changes in clast concentration; pebble fabrics generally weak (Fig. 4-3, Table 4-2); contacts between diamictons and sorted sediment vary from gradational to erosional, commonly loaded.	Subaqueous debris flow in a proximal glaciolacustrine environment
C-Interstratified diamicton and sorted sediments	Diamicton, gravel, sand, silt and clay; diamicton beds similar to those in Facies B but are <80% and generally <40% of the deposit and not as laterally continuous; sorted sediments range from clay to gravel and are most commonly sands; contacts between beds vary from conformable to erosional, commonly loaded (Plate 4-1C).	Subaqueous debris and sediment gravity flows in a proximal glaciolacustrine environment
D-Coarse Gravel	Pebbles to boulders; matrix dominantly coarse to medium sand (Fig. 4-2); dominantly normally graded (Plate 4-1E) with rare massive (Plate 4-1D) and inverse grading; lower contacts vary from conformable to erosional.	Various sediment gravity flows in a subaqueous environment

Table 4-1: Description and interpretation of facies.

Facies	Grain size and structures	Interpretation
E-Sand	Sand with minor silt and small pebbles; dominated by normal grading and A and B type climbing ripples (Plate 4-1G); stratification generally horizontal to gently dipping, rarely up to 15°; channels in lower portions common.	Deposition by turbidity currents in outwash systems
F-Well stratified silt and clay (rhythmites)	Silt and clay; variable rhythmites from thick silt capped by clay (Plate 4-1H) to laminated silt and laminated silt and clay (Plate 4-1E); lower contacts conformable.	Deposition by turbid underflow and suspension in a distal glaciolacustrine environment
G-Deformed facies	Diamicton, gravel, sand, silt, and clay; internal bedding, where present, is commonly convolute or undulatory (Plate 4-1F); folding and faulting common; breccias, clastic dikes and water escape structures are common.	Slump and slide deposits (sensu Stow, 1986)
H-Gravel overlain by sand	Gravel and sand; occurs as one fining upward package; generally well stratified	Fluvial and glaciofluvial gravel overlain by overbank sand

Table 4-1(Cont.): Description and interpretation of facies.

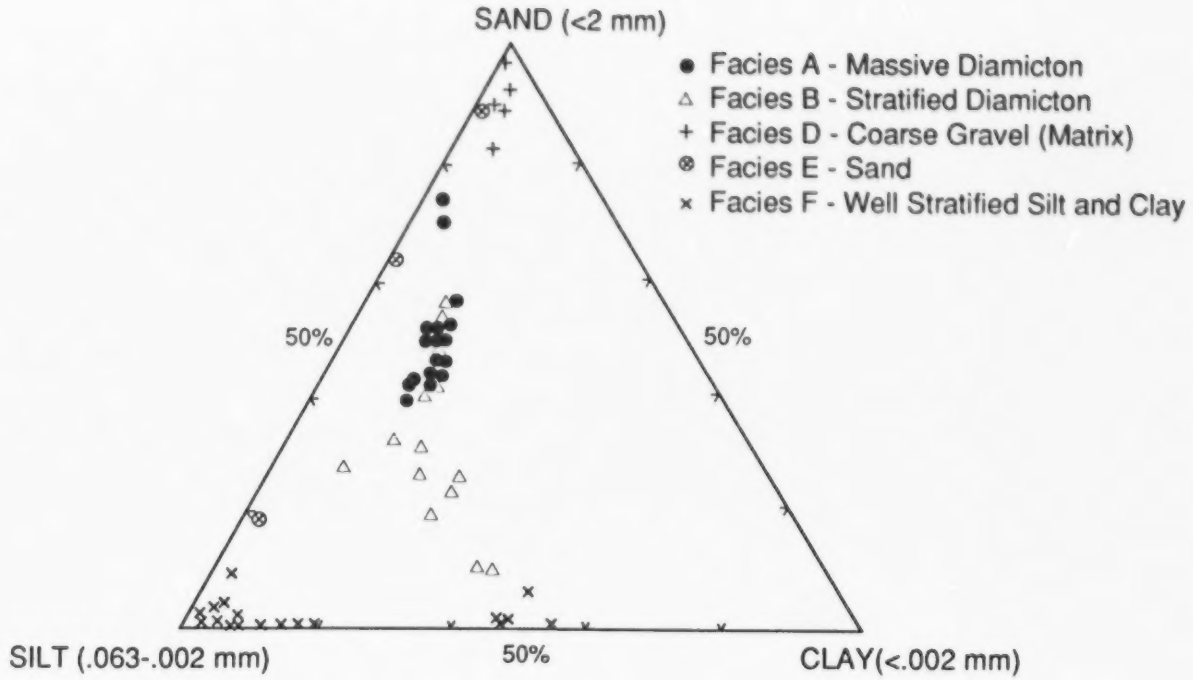
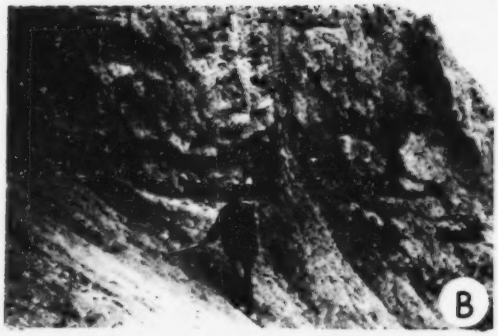


Figure 4-2: Ternary diagram of grain size of selected facies.

Plate 4-1. Characteristic examples of facies in the study area. 1A: Facies A-Massive Diamicton; 1B: Facies B-Stratified Diamicton-Section 7; 1C: Facies C-Interstratified Diamicton and Sorted Sediments-Section 4A, thin diamicton stringers within massive to weakly bedded sands, loading feature is identified with an arrow; 1D: Facies D-Coarse Gravels (massive with flame/roll-over structure)- Section 8; 1E: Facies D-Coarse Gravel (normally graded) and Facies F-Well Stratified Silt and Clay- Section 7; 1F: Deformed Sediment; 1G: Facies E-Sand with Abundant Cut and Fill Structures and thin bed of Facies D-Section 6, middle portion, 90 cm long ice-axe for scale; 1H: Facies G- Well Stratified Sand, Silt and Clay-fining upward, laminated silt and clay erosivly capped by coarse silt.

A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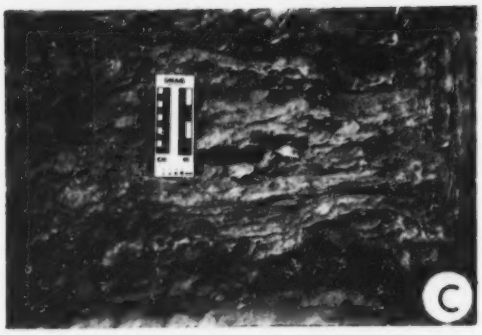
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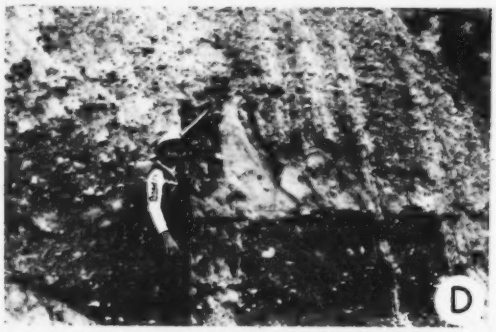
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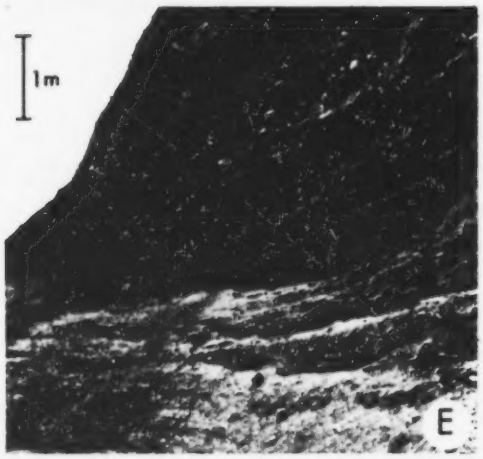
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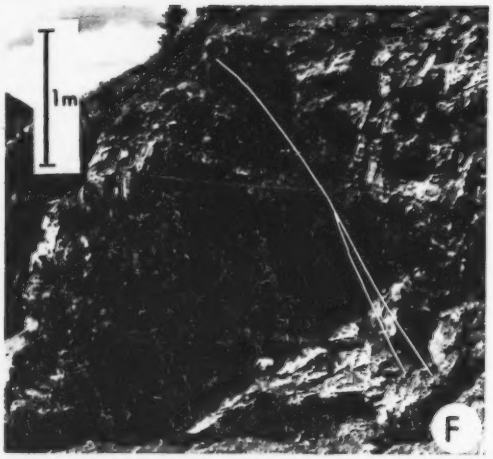
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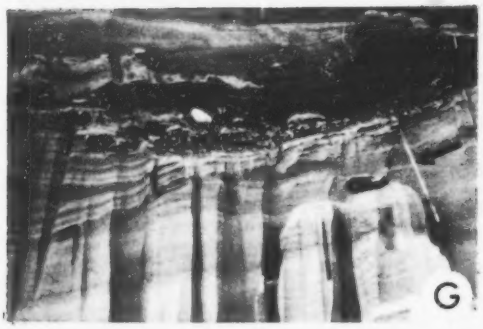
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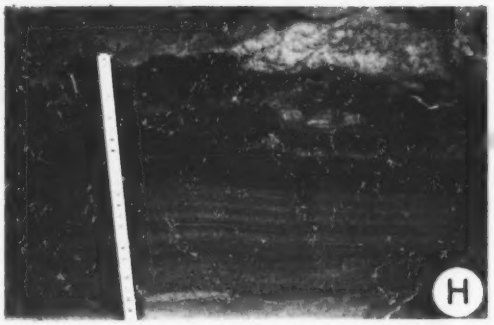
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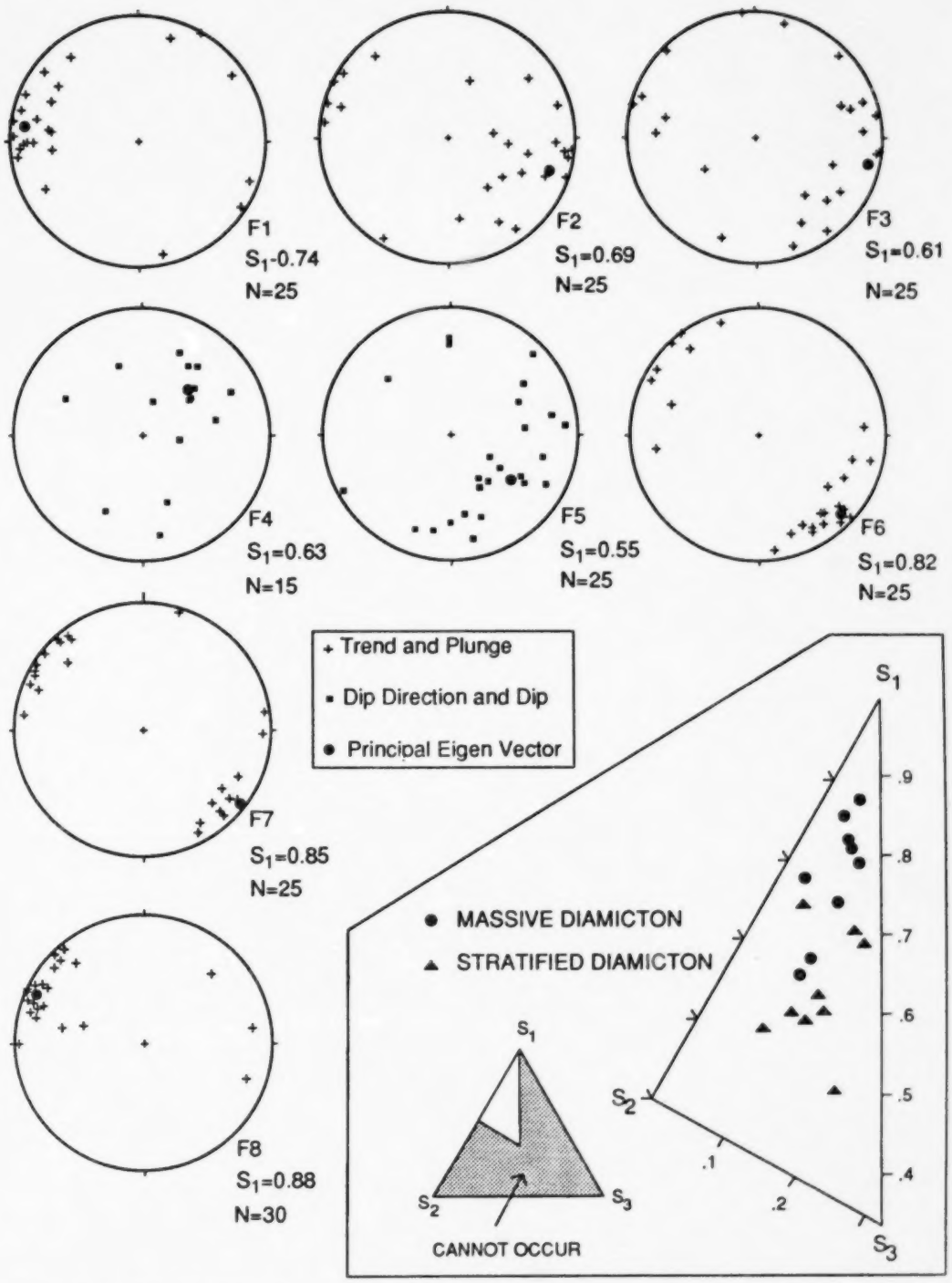


Fig. 4-3. Equal area stereonets of fabrics from Sections 4A and 8. Complete data given in Table 4-2. Inset shows ternary plot of fabric strengths for massive and stratified diamicton (modified after Lawson, 1979).

Number	Number of clasts	Principle Vector Trend	Plunge	Eigenvalues S1	S2	S3
F1	25	277	12	0.74	0.21	0.04
F2	25	108	17	0.69	0.17	0.14
F3	25	104	9	0.61	0.30	0.09
F4	15	45	48	0.63	0.23	0.14
F5	25	128	39	0.55	0.33	0.11
F6	25	134	9	0.82	0.12	0.06
F7	25	128	2	0.85	0.11	0.04
F8	30	296	9	0.88	0.09	0.04

Table 4-2: Data from fabrics mentioned in the text.

facies. Sections are described from four geographic areas to show the spatial distribution of facies: 1) the Anvil Creek area (Sections 1 to 8); 2) the Fishook Creek area (Section 9); 3).the Safety Pin Bend area (Sections 10 and 11); and 4) the confluence of the Pelly and Macmillan rivers (Section 12 to 15). The deglacial sedimentary environment is then reconstructed to explain deposition in the Pelly River valley.

Distribution And Interpretation Of Facies

Anvil Creek Area

The Anvil Creek area occurs at the eastern edge of the study area (Fig. 4-1). The irregular, hummocky topography (Plate 4-2) is likely the result of the melting of buried ice. The descriptions and interpretations are divided into two parts: sections 7 and 8 contain sediments representing an oscillation of the ice front; and sections 1 through 6 represent deglacial sequences.

Section 7 & 8

Stratigraphic logs of sections 7 and 8 are shown in Fig. 4-4. Because of the disparity of units between the two sections, they are described and interpreted separately.

Description section 8

Unit 1 consists of a wedge of poorly sorted gravel that pinches out to the west. Overall, the gravel is moderately stratified, rarely cross stratified, consisting mostly of pebbles and cobbles, although some boulders are present. Diamicton clasts >2 mmoccur in the upper third. Matrix texture is dominantly medium and coarse sand, however, it does contain zones which are poorly sorted (56% sand, 30.5% silt and 13.5% clay) especially within 30 cm of the upper contact.

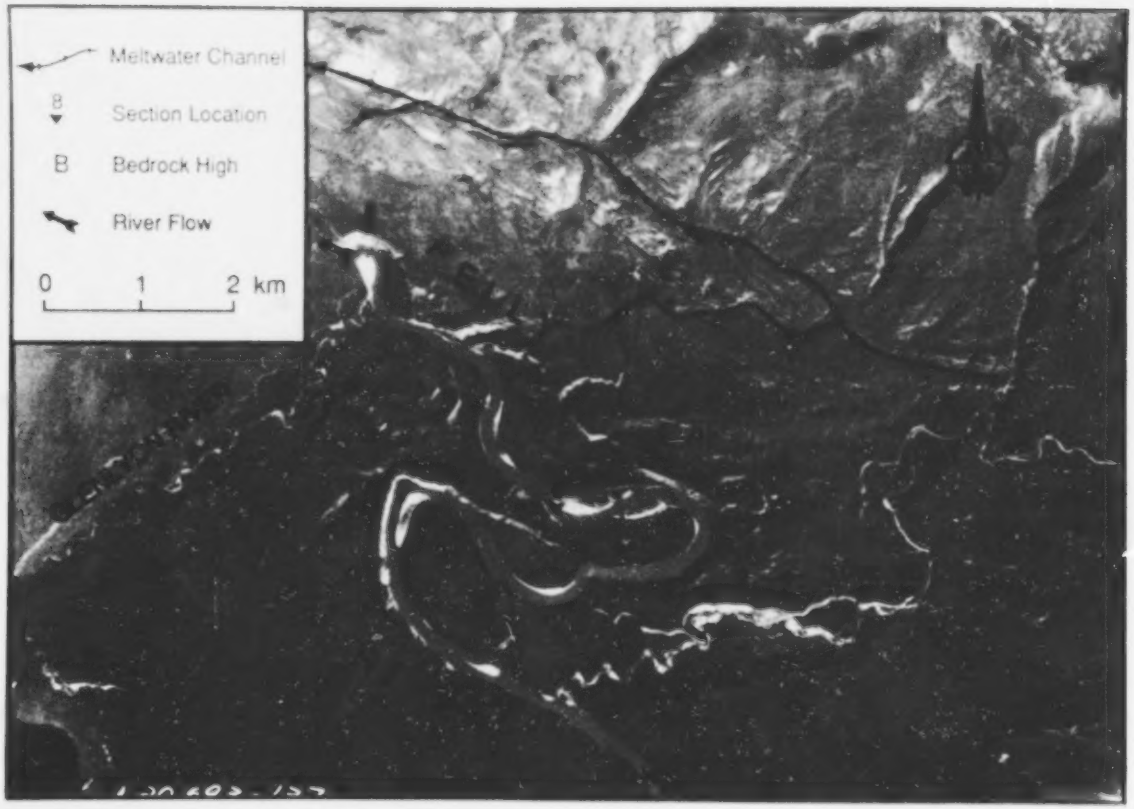


Plate 4-2: Air photograph of the Anvil Creek area with the locations of Sections 2 thru 8. Section 1 occurs just to the south of the area shown in the photograph. National Air Photo Library A20693 - 137.

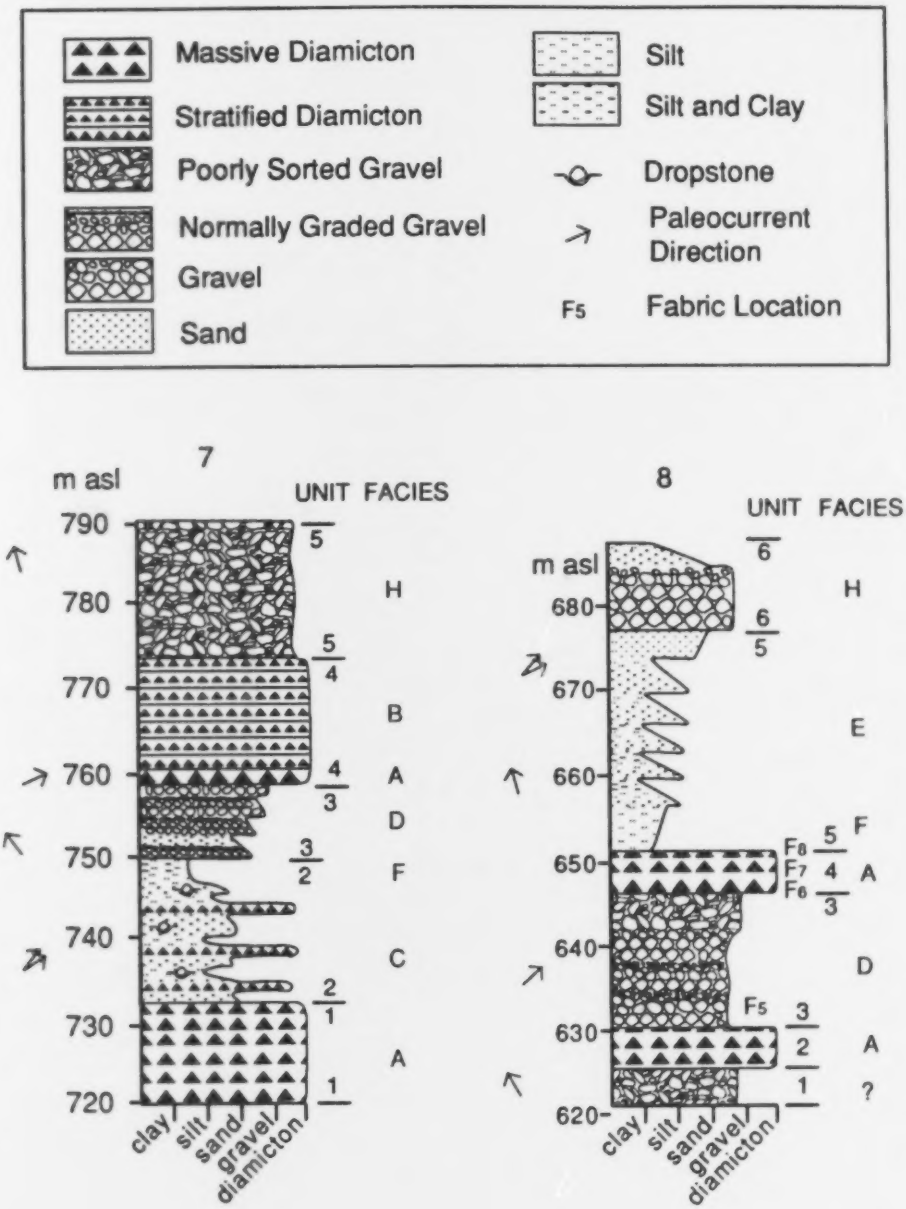


Figure 4-4: Stratigraphic logs of sections 7 and 8, locations of sections given in Fig. 4-1 and Plate 4-2. Note elevation difference between sections

Unit 2 consists of massive diamicton (Facies A). The lower contact is generally gradational over 5 to 10 cm with the lower 50 cm of the diamicton containing >50% clasts > 2 mm. Above this gradational zone the diamicton has a concentration of clasts >2 mm of 25-35% that are mostly large pebbles with some boulders up to 85 cm. Some clasts >2 mmare striated erratics that originate in the Selwyn Mountains. The diamicton is highly indurated so no fabrics were obtained. The matrix contains diffuse sandy zones (74% sand, 25% silt & 5% clay) but overall, is dominantly silty sand (51% sand, 36% silt & 13 % clay). Scattered thin, elongate layers of sand and gravel up to 9 cm thick and 3 m long are present.

Unit 3 is a thick sequence of coarse gravel (Facies D). The lower contact is sharp and possibly erosive. The lower 3 m is massive with cobbles and rare boulders supported in a matrix of pebbles, granules and sand. Upward, this grades into 4 to 5 m of normally graded beds (from pebbles and cobbles to coarse sand) up to 30 cm thick. A fabric obtained in one of these layers indicates flow approximately downvalley (F5, Fig. 4-3). Above this are 5 to 6 m of generally massive gravel, consisting of subunits up to 2.5 m thick, with minor normal grading in their upper ~50 cm, interbedded with well stratified silts (15% sand, 82% silt & 3% clay). Contacts between silt and gravel are planar and commonly erosive with one example of a large flame/roll-over structure observed (Plate 4-1D). This structure shows flow towards the north west, transverse to the valley. In the upper 4 m the gravel becomes more poorly sorted and chaotic and appears disrupted; bedding is not distinct and angular clasts of sand are present (Plate 4-3).

Unit 4 is another massive diamicton (Facies A)(Plate 4-3). The lower contact is sharp and gently undulates across the section. Concentration of clasts >2 mm is 25-30% that are mostly large pebbles. Many clasts >2 mmare

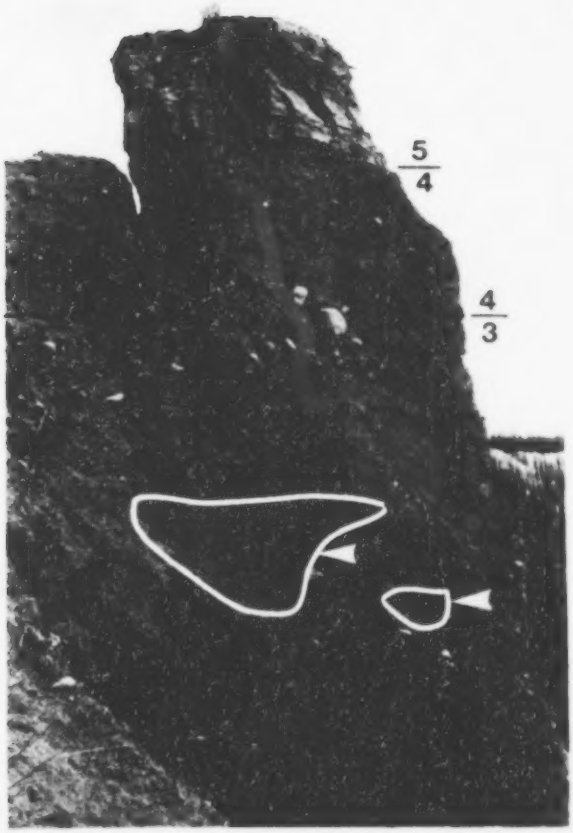


Plate 4-3: Detail from Section 8. At the base is the upper, chaotic, poorly sorted portion of Unit 3 (Facies D) with two large sand clasts outlined and indicated by arrows. Above this gravel is the massive diamicton of unit 4 (Facies A) which is 1.5 m thick. This is sharply overlain by the lower portion of unit 5 consisting of laminated to finely bedded silt (Facies F).

striated and faceted, with some derived from the Selwyn Mountains. Fabrics (F6, F7 and F8) show strong clustering oriented parallel to the valley (Fig. 4-3, Table 4-2). The matrix is more uniform than the lower diamicton, ranging from 45 to 50% sand, 35 to 40% silt and ~15% clay. Scattered thin, discontinuous silt, sand and gravel lenses are present.

Unit 5 consists of an overall coarsening upward sequence from silt (Facies F) to sand (Facies E). The lower contact is sharp and distinct (Plate 4-3). The lower ~4 m is very thinly bedded to laminated silt (Facies F) (Plate 4-3). The middle ~18 m is an overall coarsening upward sequence comprised of seven fining upward subunits. The lowest subunit consist of fine sand (Facies E) graded to silt (Facies F), and the upper subunit consists of medium and coarse sand (Facies E) graded to very fine sand (Facies F). Each sand contains several sets of type A to type B climbing ripples (cf Jopling and Walker, 1986), commonly truncated by graded beds. The uppermost set of climbing ripples show an increase in angle of climb and is then draped by laminae of silt or very fine sand (Facies F). The climbing ripples indicate flow to the north, transverse to the valley. The upper ~3 m of unit 5 consists of recessive, medium and coarse sand (Facies E) that appears to be either structureless or normally graded.

Unit 6 is a thick recessive gravel overlain by sand (Facies H). The lower contact is sharp and probably erosive. The gravel is moderately stratified with alternating open work layers and layers with a matrix of coarse sand and granules. Clasts are up to 15 cm at the base but fine abruptly to small pebbles. The gravel is abruptly capped by 40 cm of interbedded sand and fine pebble gravel.

Interpretation section 8

Units 2 and 4 at section 8 consist of massive diamicton (Facies A). Massive diamicton can form in a variety of environments, both nonglacial and glacial (Dreimanis, 1988, Levson and Rutter, 1989; Mills, 1991). Massive diamicton (Facies A) in the study area is interpreted as basal till, mainly on the basis of striated and faceted clasts, strongly oriented clast fabric and their dense, massive nature. Striated and faceted clasts indicate a period of basal transport. Strong unimodal fabrics generally indicate glacial deposition (Mills, 1991 and references therein) and where measured most massive diamictons have principle eigenvalues >.75 (Fig. 4-3). The strong fabric and their dense, massive nature indicate little or no reworking (Levson and Rutter, 1986, 1989) and that they are likely a primary or orthotill (Dreimanis, 1988). These basal tills likely formed from a combination of meltout and lodgment processes, and commonly it is difficult to determine which process dominated (Haldorsen and Shaw, 1982). Where present, the sorted lenses preclude particle by particle lodgement.

While units 2 and 4 are interpreted as having equivalent depositional histories, greater certainty is placed on the interpretation of unit 4 because of its strongly oriented fabric; however, no fabric data for unit 2 was obtained. Gradational lower contacts similar to those observed have been reported from basal meltout tills (Levson and Rutter, 1988), and the sand rich zones in the lower diamicton indicate a washing process, commonly associated with basal meltout (Haldorsen, 1981, 1983). Unit 2, however, may not be a till; it could represent debris flow deposition.

Unit 3 consists of coarse gravel (Facies D). Coarse gravel can be deposited in a wide variety of environments: alluvial and glaciofluvial (Rust and Koster, 1984); marine (Nemec and Steel, 1984); and deltaic (Nemec and

Steel, 1989). The coarse gravel (Facies D) between the two diamictons is interpreted as resulting from sediment gravity flows into a subaqueous environment. This is based on the dominance of normal grading and the interstratification of fine-grained sediment (c.f. Rust and Romanelli, 1975; Walker, 1975; Lowe, 1982; Nemec and Steel, 1984; Postma, 1984). At the base, the gravel is poorly sorted and likely represents relatively more rapid deposition and shorter transport distances than the sediments above which are better sorted (cf. Nemec and Steel, 1984). The normally graded beds were likely deposited by high density turbidity currents (cf. Lowe, 1982; Nemec and Steel, 1984). The interstratification of the silt layers represents quiet conditions between flow events. The presence of the flame/roll-up structure (Plate 4-1D) and the lack of structure in the associated gravel implies rapid emplacement and could indicate deposition by disorganized cohesive flow (Lowe, 1982). The orientation of the flame/roll-up structure represents the flow direction of the overlying gravel (W. Nemec, personal communication, 1992). Upward, the gravel becomes more chaotic and contains clasts of sand. This could represent a disturbance by glaciotectonism (Aber *et al.*, 1989) or emplacement by debris flows incorporating intraclasts (Nemec and Steel, 1984). The lack of well defined faults or folds appears to support the latter.

The interpretation of the coarse gravel of unit 1 is problematic. This gravel lacks the interstratified fine sand and silt of unit 3 and contains cross stratification which generally indicates tractional deposition under unidirectional currents (Nemec and Steel, 1984, Morison and Hein, 1987, Deimer, 1987). The presence of clasts of diamicton suggests a glacial environment or, at least, the presence of previously deposited diamicton. Based on stratigraphic position, the unit could represent glaciofluvial gravel

deposited during glacial advance or subglacial deposition in a Nye channel (cf Shaw, 1985).

The base of unit 5 consists of thinly bedded silt (Facies F). On the basis of stratification and grain size, this sub-unit is interpreted as representing distal deposition in a glacial lake (cf Pickrill and Irwin, 1983; Ashley *et al.* 1985; Catto, 1987; Liverman, 1991). The stratification rules out aeolian deposition, and the grain size suggests deposition in a low energy environment, likely from a combination of distal underflow currents and suspension settling. The very sharp lower contact indicates an abrupt shift from glacial deposition to glaciolacustrine deposition.

The majority of unit 5 consists of sand (Facies E). Sand such as this could represent fluvial, glaciofluvial or deltaic sedimentation (Miall, 1984; Walker and Cant, 1984), but it is interpreted as "deltaic". This interpretation is made on the basis of its thickness, the absence of internal truncations, the coarsening upward nature, the stratigraphic position and the presence of climbing ripples and normal grading. The presence of ~20 m of sand generally precludes fluvial deposition, both fluvial and glaciofluvial deposits would have abundant internal truncations and the coarsening upward nature suggests a deltaic deposit. The gradational lower contact with distal glaciolacustrine deposits suggests no rapid change in depositional environment. Type A to B transitions of climbing ripple sets similar to those in the lower portion of Facies E have been widely reported in Pleistocene glacial lake sequences as representing waning turbid underflows (Jopling and Walker, 1968, Gustavson, 1975; Gustavson *et al.*, 1975, Ashley *et al.*, 1985).

The presence of seven fining upward subunits in unit 5 implies seven depositional events by turbid underflows. Each subunit contains several sets of climbing ripple sequences and normally graded sand, indicating that each

major flow was composed of a series of pulses which progressively declined (cf. Ashley *et al.*, 1985; Liverman, 1991). The draped laminae at the top of each subunit demonstrates a transition from current deposition to suspension settling (cf. Jopling and Walker, 1968, Gustavson, 1975; Gustavson *et al.*, 1975, Ashley *et al.*, 1985). It is not clear whether these beds represent annual sedimentation or shorter time-scale energy fluctuations (cf Ashley *et al.*, 1985). This sand (Facies E) was likely deposited on the lower- to mid- slope of a subaqueous cone or delta.

The coarser sand (Facies E) at the top of unit 5 implies more proximal deposition and the normal grading likely represents proximal turbidites or slump surges (cf. Shaw, 1977; Ashley *et al.*, 1985). This sequence of sand (Facies E) probably was deposited on the mid- or upper- slope of a subaqueous cone or delta..

The gravel to sand and silt sequence (Facies H) is interpreted as glaciofluvial deposits on the basis of its stratigraphic position and stratification. This layer represents deposition either as topsets as a delta prograded into a lake or by the Pelly River as it began to cut down through the valley fill sequence.

Description section 7

Unit 1 is a massive diamicton (Facies A). The lower contact is covered, with the lowest exposure occurring 5 m above the Glenlyon River. This diamicton is similar to those described at section 8 but has rock types dominated by extrusive volcanics (48%) from a local source on the east side of Glenlyon Valley (Campbell, 1967), but also contain clasts >2 mmderived from Selwyn Mountains.

The lower ~15 m of unit 2 is interstratified diamicton and sorted sediment (Facies C). The lower contact is sharp, horizontal to slightly undulatory and is marked by a 10 to 20 cm sandy, small pebble gravel. The lower 2 m consists of interstratified sandy pebble gravel, medium sand and diamicton. Above this, the amount of gravel and diamicton decreases, and the deposit becomes mainly interstratified sand and silt. The diamicton layers are similar to the massive diamicton described above in terms of concentration of clasts >2 mm and matrix composition but comprise <50% of the unit. The layers are up to 45 cm thick, lenticular, laterally discontinuous, contain intraclasts of sand and silt and decrease in occurrence upward. The gravel layers are generally thin, 10-15 cm, and have a matrix of coarse sand and granules. The sand layers are dominantly normally graded, commonly contain intraclasts of silt, sand and diamicton at the base and some display contorted bedding. The silt layers increase in occurrence upward and generally drape the underlying beds. Lower contacts of gravel on sand always display load features, such as ball and pillow and flame structures (loading structures), and commonly other contacts are similarly loaded. Clasts, up to 60 cm, which deform underlying bedding and are draped by overlying strata (clasts deforming bedding) occur throughout.

The upper ~2 m of unit 2 consist of finely bedded to laminated silt with minor fine sand and clay (Facies F) (Plate 4-1E) containing clasts deforming bedding of up to 20 cm. The lower contact is gradational over 1 m.

Unit 3 consists of a coarsening upward sequence of normally graded coarse gravel (Facies D) (Plate 4-1E). The lower contact is gradational (Plate 4-1E). The unit coarsens upward from small pebble gravel capped by medium sand to boulder and cobble gravel that is abruptly capped by very coarse sand and granules. Clasts of diamicton up to 35 cm are present. The unit contains

interbeds of well stratified fine sand and silt and rare diamicton layers. Contacts throughout the unit are generally conformable and planar; although, erosional surfaces do occur, mainly where gravel overlies silt or sand. Some gravel beds pinch out laterally. The dip of these beds increases upward to ~20° and indicates flow towards the northwest.

Unit 4 is a diamicton complex, 15 m thick, consisting of massive (Facies A) and stratified (Facies B) diamicton. The lower contact is sharp, distinct and gently undulatory; it truncates the dipping strata in the underlying gravel and dips gently towards the center of the Pelly River valley. In the lower 1 m the diamicton is dense and massive (Facies A), similar to Unit 1. However, in contrast to unit 1, rock types are not dominated by extrusive volcanics (8%); instead, rock types are dominated by rocks from the Selwyn Mountains and Tintina Trench. The majority of unit 4 consists of stratified diamicton (Facies B)(Plate 4-1B). Concentration of clasts >2 mm is 15 to 30% that are mostly pebbles with some boulders and many are striated. Matrix consists of silty sand. The diamicton is stratified on the 0.1 to 2.5 m scale and is broadly folded (Plate 4-1B). The thicker strata are separated by sand and laminated silt layers up to 30 cm thickness (Plate 4-1B) and are further subdivided by <5 cm silty sand layers every 10 to 30 cm. The nature of these sorted sediments are described in more detail in *Description sections 1 to 6*.

Unit 5 consist of a wedge of poorly sorted gravel (Facies H) that pinches out to the east. The gravel (Facies H) is weakly stratified, composed of pebbles and cobbles and has a sandy matrix.

Interpretation section 7

Unit 1 consists of massive diamicton (Facies A) and is interpreted as basal till for similar reasons to those described for section 8. As with unit 2 at

section 8, the lack of fabric data makes the interpretation somewhat problematic. The abundance of volcanic clasts in this diamicton indicate flow northwest along Glenlyon Valley.

Unit 2 consists of interstratified diamicton and sorted sediment (Facies C) which generally have been interpreted as representing deposition in some type of a glaciolacustrine environment (Evenson *et al.*, 1977; Eyles and Eyles, 1983; Liverman, 1991). Complex deposition in a subaqueous environment is indicated by the wide range of grain sizes and the abundance of soft sediment deformation features. Diamicton strata are interpreted as deposited by debris flow based on their lenticular shape and loaded lower contacts. The gravel likely represents high energy sediment gravity flow. The graded sand beds point to deposition by proximal turbidity currents and the silt beds represent more distal turbidites. The clasts deforming bedding are interpreted as dropstones from icebergs. These data indicate an ice-contact, proximal glaciolacustrine environment.

The upper ~2 m of unit 2 consists of finely bedded to laminated silt and clay (Facies F) and is interpreted similarly to the base of unit 5 at section 8: deposition by distal turbidites and suspension settling. The difference here is that the presence of silty clay layers indicates there was more deposition by suspension. The clasts deforming strata are interpreted as dropstones from icebergs. The gradational lower contact indicates a gradual shift to more distal conditions than represented by the underlying sediments.

Unit 3 consists of a thick coarsening upward sequence of gravel (Facies D) and is interpreted as deposited by sediment gravity flows, similarly to unit 3 at section 8. The increase in angle of dip upward indicates that the sediment represents some type of deltaic deposit with flow towards the northwest.

The diamicton complex of unit 4 with its lower erosive contact and large thickness is interpreted to represent overriding by a glacier. The lower 1.5 m of massive diamicton (Facies A) is thought to represent a till based on the erosive lower contact, striated and faceted clasts, and its massive nature. Other supporting evidence for a glacial advance is the underlying coarsening upward sequence. However, this could also represent a more massive intrabed of the stratified diamicton. The rock types indicate that this glacier advanced from the Tintina Trench rather than from the Glenlyon River valley.

Most of unit 4 consists of stratified diamicton (Facies B). Diamicton stratified with sorted sediments has been interpreted to form by basal meltout with stratification formed by meltwater from debris poor bands in the ice (Shaw, 1979), by basal melting and quiet water sedimentation beneath floating ice (Gibbard, 1980), by subaerial debris flow followed by pore water expulsion and overland flow (Lawson, 1979) and by subaqueous debris flow followed by deposition of sorted sediment (Evenson *et al.*, 1977; Eyles and Eyles, 1983; Shaw, 1987). The stratified diamicton examined in the study area is interpreted as having formed by cohesive debris flows in a subaqueous environment based mainly on the weak fabric strengths and the nature of the interstratified sorted sediment. Fabrics obtained from stratified diamictons (Facies B) are generally weaker and have girdle patterns in contrast to those from the massive diamicton (Fig. 4-3). Both these characteristics have been observed in debris flows (Lawson, 1979; Mills, 1991). Compared to the massive diamicton, the smaller average clast size, which indicates a lower carrying capacity, and the finer grain size of the matrix also support a flow origin (Nemec and Steel, 1984). The striated clasts indicate a glacial origin for the diamicton material, either directly from the glacier or from previously deposited glacial diamicton. The well stratified nature is caused by sorted

material being deposited between diamicton flow events. A more complete interpretation for the sorted material is given in *Interpretation section 1 to 6.*

The overlying gravel is interpreted as glaciofluvial based on similar arguments as the overlying gravel at section 8.

Interpretation section 7 and 8

These sections, with two tills separated by stratified sediments, indicate a fluctuating ice front within the Tintina Trench. Rock types suggest that the diamicton of unit 1 at section 7 represents ice flow along the Glenlyon River valley. The subsequent advance was from ice that flowed down the Tintina Trench rather than the Glenlyon River valley. If units 4 at both sections represents the same event, it indicates a readvance of ice in Tintina Trench of at least 3 km.

Section 1 to 6

Sections 1 through 6 represent deposits and events that followed the deposition of the last massive diamicton (Facies A) observed in the area. Stratigraphic logs are shown in Fig. 4-5.

Description Sections 1 to 6

Examination of the base of sections along Anvil Creek, sections 2, 3 and 4A and B (Fig. 4-5), exposes a wedge of stratified diamicton (Facies B) that thins towards the center of the valley. This diamicton consists of ~5 to 35% clasts > 2 mm, mostly small pebbles with some boulders up to 40 cm, with many being striated, and intraclasts of silt and sand. Fabric data from section 4A indicates a WNW-ESE orientation with moderate strength and a girdle pattern (F1, F2, F3 in Fig. 4-3, Table 4-2). The matrix consists dominantly of

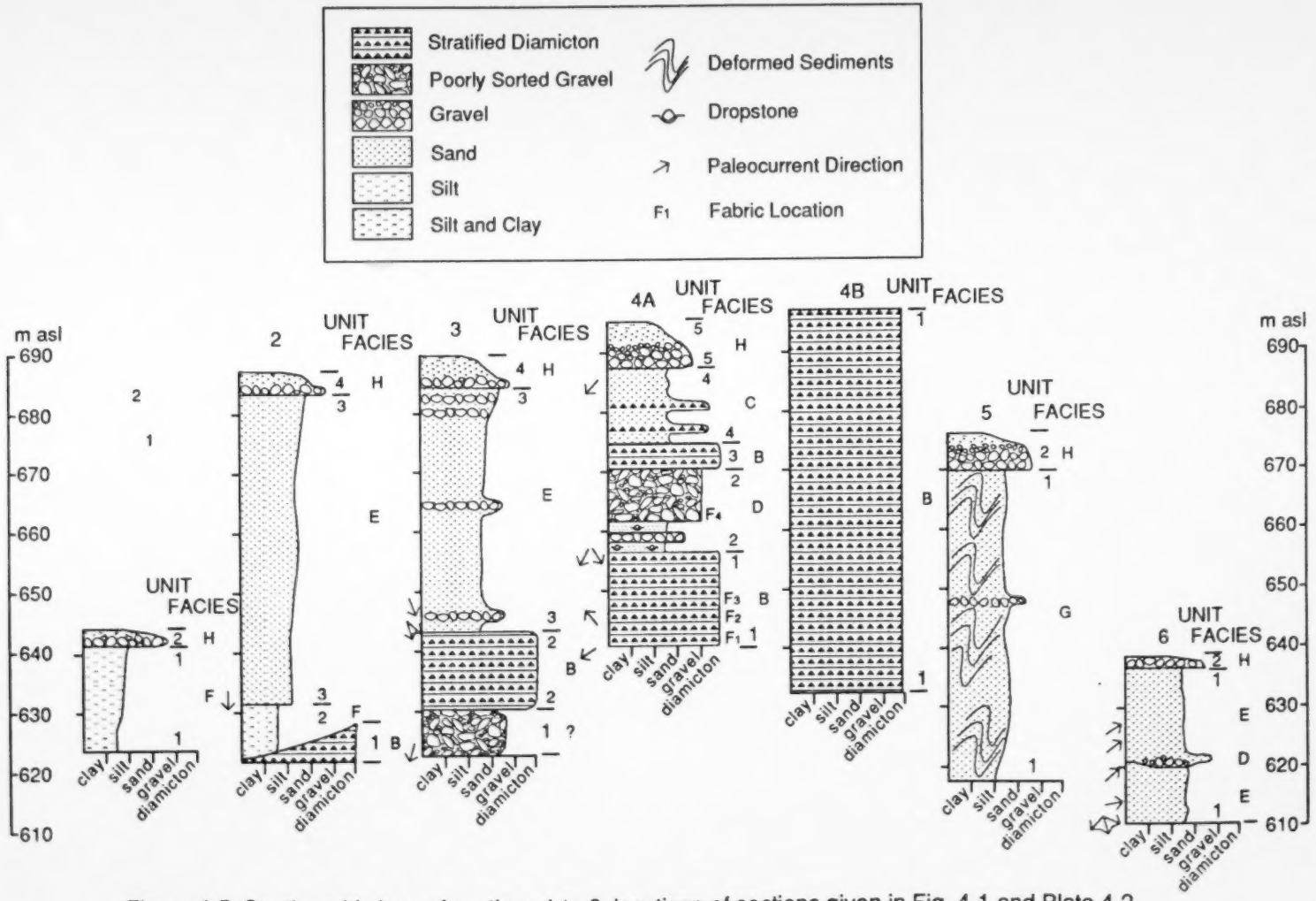
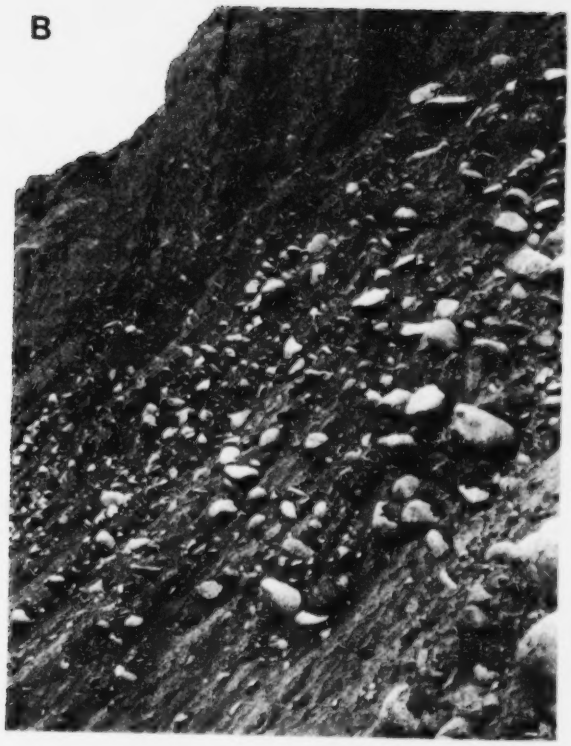


Figure 4-5: Stratigraphic logs of sections 1 to 6, locations of sections given in Fig. 4-1 and Plate 4-2.

silty sand, although some silt rich zones occur (28% sand, 62% silt, & 11% clay). Stratification on the 1-2.5 m scale is marked by color changes, from dark grayish brown (2.5Y 4/2) to light grey (5Y 6/1) to very dark grey (5Y 3/1), and by sand layers which are up to 40 cm thick and 10's of meters long (Plate 4-4). The sand layers are generally normally graded and can contain ripples, clasts deforming bedding (up to 20 cm) and diamicton stringers up to 2 cm thick. This large scale stratification gently undulates and dips at ~10° towards the center of the valley. Many of the thicker diamicton beds are subdivided on the 2 to 80 cm scale by sorted layers up to 8 cm thick and 5 m long. Sorted layers are dominantly sand similar to those described above. Also present are some laminated silt and clay, clayey silt and pebble gravel layers. Many of the sorted layers have lower gradational contacts while others simply drape the underlying diamicton.

Unit 2 at section 4A is a wedge of sorted sediment that thins eastward (Plate 4-4A). The lower contact is gradational with a thin clayey-silt (4.2% sand, 63% silt, & 33% clay) layer draping the underlying diamicton. The lower 4 to 5 m consists of interstratified fine rippled sand (Facies E) and gravel normally graded from cobbles to granules (Facies D). The sand contain clasts deforming bedding and ripples which indicate flow to the south and south west. The rest of the unit consists of massive coarse gravel (Facies D) with large boulders supported in a sandy pebble matrix (Plate 4-4B) which pinches out to the east. The large boulders, many with a maximum dimension up to 60 cm, have a strong visible fabric indicating flow towards the south west (Plate 4-4B), and 15 measured cobbles and boulders confirm this (F4, Fig. 4-3). Some lenses of a massive, clayey silt (7% sand, 61% silt, & 32% clay) with occasional pebbles occur between the gravel and the overlying stratified diamicton.



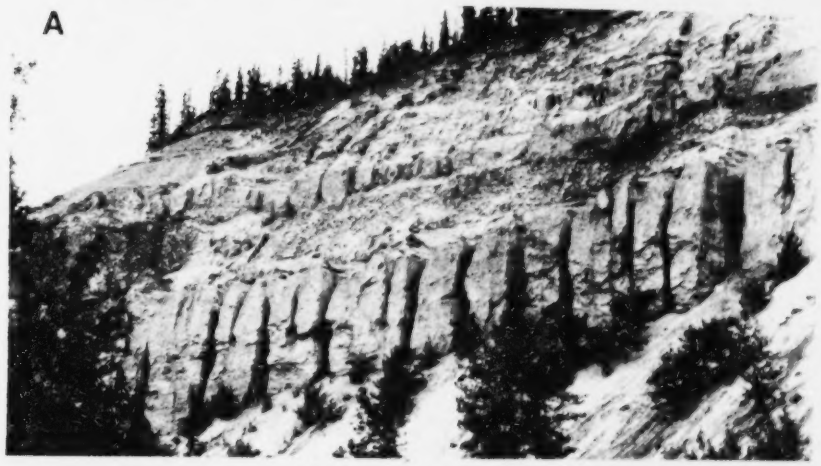


Plate 4-4. 4A: Section 4A with wedge of coarse gravel (Facies D) within stratified diamicton (Facies B). Height of the visible portion of the section is approximately 50 m. 4B: Detail of the coarse gravel showing the well developed imbrication.

Unit 3 at section 4A is comprised of stratified diamicton (Facies B) the same as unit 1. The lower contact is gradational, interfingering where it overlies sand but is sharp and distinct where it overlies the coarse gravel.

Unit 4 at section 4A consists of interstratified diamicton and sorted sediment (Facies C) and is similar to unit 2 at section 7. The lower contact with unit 3 is gradational, and eastward, toward section 4B, the unit interfingers with stratified diamicton (Facies B). There is less gravel and more sand than at section 7. Although much of the sand is normally graded, some is massive to weakly stratified (Fig. 3C) and commonly contains abundant dish structures. Thin diamicton stringers, like those shown in Fig. 3C, generally only have small pebbles and granules as clasts.

Unit 3 at section 3 consists of sand (Facies E) and minor amounts of gravel (Facies D). The lower contact dips gently to the west and is marked by a gravel lag deposit. The lower half of unit 3 has different structures than unit 5 at section 8. Channel-like forms are present which truncate bedding and are filled with similar material (Plate 4-1G). Dips of up to ~10-15° were observed in the lower 5 m of the unit, above this observed dips were <5°. Stratification is well defined, commonly by normal grading, climbing ripples and ripples. Ripples and dip of bedding indicate flow to the south and southeast. The upper 10 m is mostly coarse sand (Facies E) which is thicker bedded and more recessive than the sand below. Cobble and pebble gravel (Facies D) occurs throughout the unit, increasing in occurrence upward.

Unit 2 at section 2 consists of well stratified silt and very fine sand (Facies F). The lower contact with the stratified diamicton of unit 1 is very sharp and distinct.

Unit 3 at section 2 is nearly identical to unit 3 at section 3, consisting dominantly of sand (Facies E) although gravel is not as common. The lower

contact is sharp, distinct and likely erosional. Ripples from the lower part of the unit suggest flow to the south.

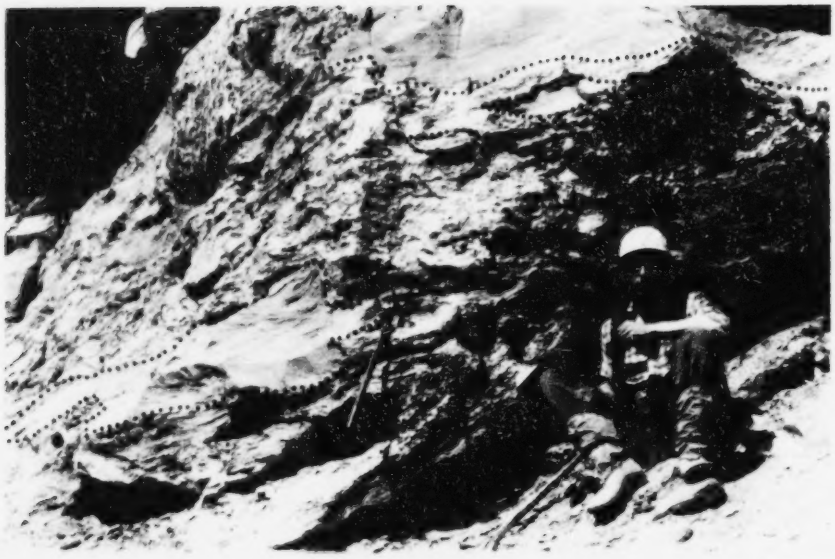
Unit 1 at section 6 is dominated by sand (Facies E) with minor amounts of gravel (Facies D). The sand is similar to that at the base of unit 3, section 3, containing abundant channel-like forms (Plate 4-1G). Gravel (Facies D) is also present and some occupies channel forms along an erosional surface that cuts across the middle of the section (Plate 4-1G). Ripples indicate southerly flow near the base and shift northeastward up section.

Section 5 is over 1 km long and varies from 10 to 60 m in height, caused by irregularities in the hummocky topography (Plate 4-2). Unit 1 consists entirely of disturbed sediment (Facies G) composed mainly of sand but ranging from silt to gravel. Gravel ranges from pebble to boulder, commonly with intraclasts of sand, some up to 1 m in diameter. Sand beds may be normally graded, but more commonly, they are highly disrupted and brecciated with intraclasts of sand (Plate 4-5). Microfaulting is common throughout, often highlighted by thin clastic dikes. Bedding is commonly folded and contorted, with those that rest directly on bedrock folded into nappe like forms with approximately horizontal axial planes.

Unit 1 at section 1 consists of well stratified silt, clay and minor sand (Facies F) and dips towards the north at ~5°. The base consists of finely bedded clayey silt (85% silt, 15% clay) which is overlain by finely bedded to laminated rhythmites of silt or very fine sand to clay. These rhythmites thin from 25-30 cm at the base to <10 cm at the top.

The uppermost units at all the sections except for 4B consist of gravel overlain by sand (Facies H) like that at unit 6, section 8. At section 5 the gravel overlain by sand (Facies H) parallels the irregular topography.

A



B

Plate 4-5. Examples of deformed sediment from Section 9. 5A: Flow breccia containing subangular clasts of sand; 5B: Base of a slump with a sharp erosive contact and imbricate thrust faults.

Interpretation section 1 to 6

Stratified diamicton (Facies B), at unit 1 section 2, unit 2 section 3, units 1 and 3 section 4A and unit 1 section 4B, is interpreted similarly to unit 5 section 7: it represents subaqueous cohesive debris flow. However, diamicton with a concentration of clasts >2 mm of <10% and a silty matrix suggests that these could be sorted beds that had abundant ice rafted clasts (Ovenshine, 1970). The fabrics and the dip of the stratified diamicton (Facies B) point to a source for debris flows, either from ice or previously deposited till, in the vicinity of the bedrock high marked B in Plate 4-2 The decreasing thickness likely points to a combination of non-deposition and erosion away from the source.

Sorted sediments within the stratified diamicton were described in more detail than at section 7. Clasts deforming bedding are interpreted as dropstones, normally graded sands as proximal turbidites and clayey silt beds as quiet water suspension settling. These data all suggest deposition in a subaqueous environment which, combined with the dominance of diamicton, points to deposition in a proximal, ice-contact lake.

Unit 2 at section 4A represents a change in the pattern of sedimentation. The interbedded rippled sand (Facies E) and normally graded gravel (Facies D) represent sediment gravity flows The wedge of coarse gravel, however, is indicative of a high energy event. Its massive nature implies that it was deposited during one event, the imbrication appears to indicate transport from a source somewhere near where Anvil Creek enters the Tintina Trench, and the occurrence of pebbly, clayey silt lenses along the upper contact implies subaqueous deposition. It is tempting to attribute this gravel to a jökulhlaup, however, the coarse grain size and lack of stratification of this sediment is radically different from subaerial jökulhlaup deposits studied in Iceland (Maizels, 1989). This gravel could also represent glaciofluvial material

deposited onto ice which later collapsed producing a high energy flow into the basin.

The interpretation for unit 4 section 4A, interstratified diamicton and sorted sediment (Facies C) is the same as for the similar sediments at unit 2 section 7: debris flows and turbidites. The presence of massive sand, abundant dish structures and loading structures in other subaqueous systems has been interpreted as indicating rapid deposition (Rust and Romanelli, 1975; Rust, 1977; Cheel and Rust, 1982; Surlyk, 1987).

Sand (Facies E) with channel-like features, present at unit 1 at section 6 and at the base of units 3 at sections 2 and 3, could represent deposition in a sandy fluvial system (Walker and Cant, 1984) or deposition in a deltaic system (Prior and Bornhold, 1988). The occurrence of normal grading and ripple and climbing ripple sequences, the lack of large scale crossbeddding, the coarsening upward association and the stratigraphic association with fine grained glaciolacustrine sediments point to deposition in a deltaic system. Cut and fill structures have been observed in both modern and ancient deltaic deposits and likely represent erosion by high density turbidity currents (Prior and Bornhold, 1988). This is supported by the presence of gravel (Facies D) in some of the larger channels. Flow indicators are generally away from the areas of stagnant ice, implying that these may have been sources for some of the sediment or that they were controlling the paleotopography.

At units 3 at sections 2 and 3 the sand (Facies E) coarsens upward and the channels are not as well developed, apparently representing more continuous deposition. The increasing occurrence of gravel (Facies D) suggests an increase in energy levels.

Disturbed sediment (Facies G) such as those exposed at section 5 could be interpreted as failure caused by the melting of supporting ice

(McDonald and Shilts, 1975) or by glaciotectonism (Aber *et al.*, 1989). Based on the lack of consistant orientation of deformation features and the intimate association with hummocky topography, deformation is interpreted as slump and slide deposits (sensu Stow, 1986) in a water saturated environment. The tight folding observed adjacent to the bedrock high was likely produced by sliding. The more disrupted and disturbed brecciated sediment is interpreted as slump deposits; previously deposited sediments brecciated during transport resulting in subangular clasts in a more massive groundmass (cf Postma *et al.*, 1983).

Unit 1 at section 1 and unit 2 at section 2 are mainly silt (Facies F) and represents distal deposition in a glacial lake as interpreted previously. Decreasing size of rhythmites upward, similar to that at unit 1, has been interpreted in other areas as a removal of source (Shaw, 1977; Fulton, 1965; Ashley *et al.* 1985).

The gravel overlain by sand (Facies H) which occurs at the top of most of the sections is again interpreted as glaciofluvial or fluvial deposition. Since the gravel overlain by sand (Facies H) at section 5 descends into kettle holes, this indicates that all the ice had not melted by the time the lake drained and gravel was deposited.

Tay River Area

Section 9 occurs approximately 10 km northwestward of section 7 in the Tintina Trench. The section is >1 km in length and up to 40 m high with an elevation of ~604 m at river level. Plate 4-6 shows the downstream part which contains downwarped sediments. Adjacent to section 9 are several large kettleholes, one being present at the downstream end (Plate 4-6). No stratigraphic logs were drawn for this section because of the lateral variability.

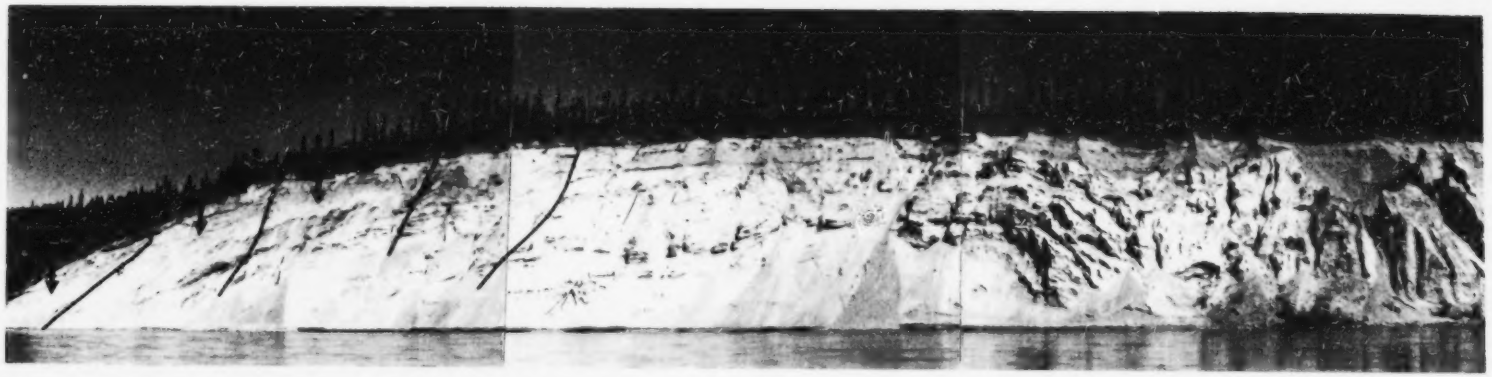


Plate 4-6: Downstream portion of Section 9, location of section given in Fig. 1. Large normal faults which displace the entire package of sediment are highlighted. The upper surface of the fourth fining upward sequence is identified by arrows. The height of the section is approximately 40 m.

Description Section 9

The downwarp area consists of gravel (Facies D) and deformed sediment (Facies G). The lowest sediment is coarse gravel (Facies D), similar to those described before; however, adjacent to the structure it is vertical. The downwarp area consists mostly of disturbed silt and sand (Facies G). Brecciation is common, often highlighted by wind erosion (Plate 4-5A). Three additional downwarping structures were observed upstream.

Downstream from the downwarped area the gravel is overlain by four sequences which generally fine upward from medium and fine sand (Facies E) to silt (Facies F) over 6 to 9 m. The sand is dominantly massive, with rare normal grading and ripples. Silt layers are generally finely bedded and flame structures are common. Clasts deforming bedding are present throughout. At the top of the third layer a gravel is in erosive contact with the underlying fine sand and silt which contains large, 3 to 4 m, angular intraclasts of silt associated with imbricate faults (Facies G)(Plate 4-5B). The fourth layer is capped by thinly bedded rhythmites of silt and clay (Facies F). These four sequences are cut by abundant normal faults, some with considerable displacement (Plate 4-6), and abundant clastic dikes. The entire sequence is tilted down towards the southwest.

The section is erosively capped by a well stratified gravel overlain by sand (Facies H). This layer is also displaced by the normal faults and descends into the kettlehole at the end of the section.

Interpretation Section 9

The gravel (Facies D) and the disturbed sediment (Facies G) are interpreted similarly to those described above; they are formed by sediment gravity flows, and slumps and slides, respectively. The elongate sand clasts

shown near the base of Plate 4-5A appear similar to phacoidal structure where zones of unsheared material occur within a sheared matrix (Bates and Jackson, 1980, p. 470). This and the imbricate faults higher in the section (Plate 4-5B) are interpreted as forming along the base of a slump, as has been reported in other studies (Martinsen, 1989; Nemec, 1990). The large downwarping structures demonstrate melting of large blocks of ice.

The four sequences of sand (Facies E) and silt (Facies F) are again interpreted similarly to those described above; deposition occurred by proximal turbidity currents, and distal turbidity currents and suspension settling, respectively. The dominance of massively bedded sand suggests rapid deposition by suspension from turbidity currents with only rarely a transition into tractional deposits. A similar dominance of massive sand has been reported from modern turbidity currents (Zeng *et al.*, 1991). The fining upward nature of the sequences suggests a cyclic decrease in the strength of the turbidity currents reaching the site, with the lowest energy represented by the laminated silt and clay at the top of the fourth cycle. Dropstones are present throughout the sequences indicating icebergs were present. The fact that all the sediments are tilted to the west and faulted indicates they were deposited onto a slab of ice which did not completely melt until after deposition of the upper gravel.

Safety Pin Bend

Safety Pin Bend is a short anastomosing reach of the Pelly River located 65 km downvalley from section 9 (Fig. 4-1). The sediments at Safety Pin Bend were deposited in a large lake basin that extended close to the western limit of glaciation. Stratigraphic logs are given in Fig. 4-6.

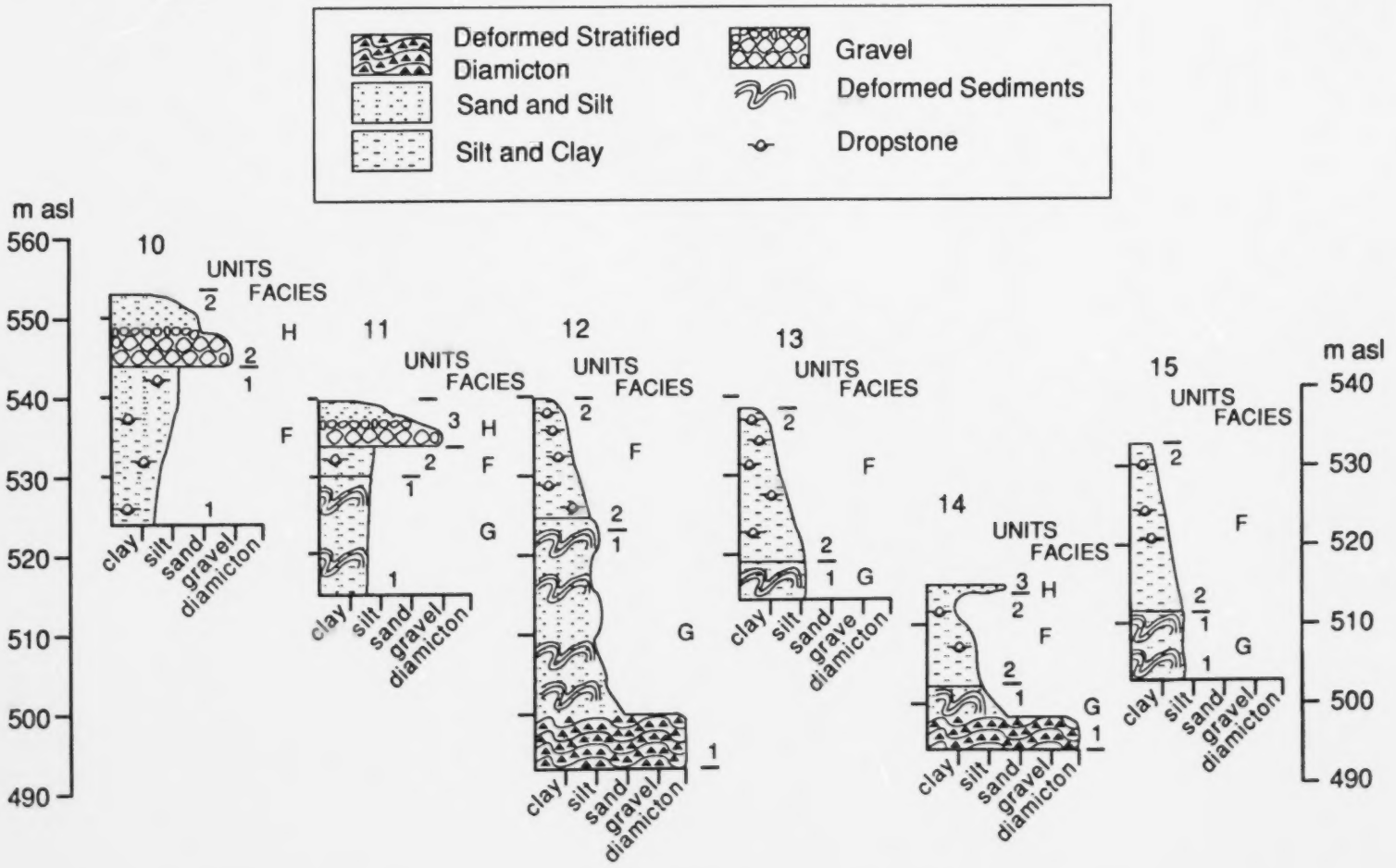


Figure 4-6: Stratigraphic logs for sections 10 to 15, location of sections shown in Fig. 4-1.

Description Sections10 and 11

The base of unit 1 at section 10 consists of laminated to finely bedded silt, very fine sand and minor clay (Facies F) that coarsens slightly upward to fine and medium sand with minor silt (Facies E). Clasts deforming bedding are present throughout.

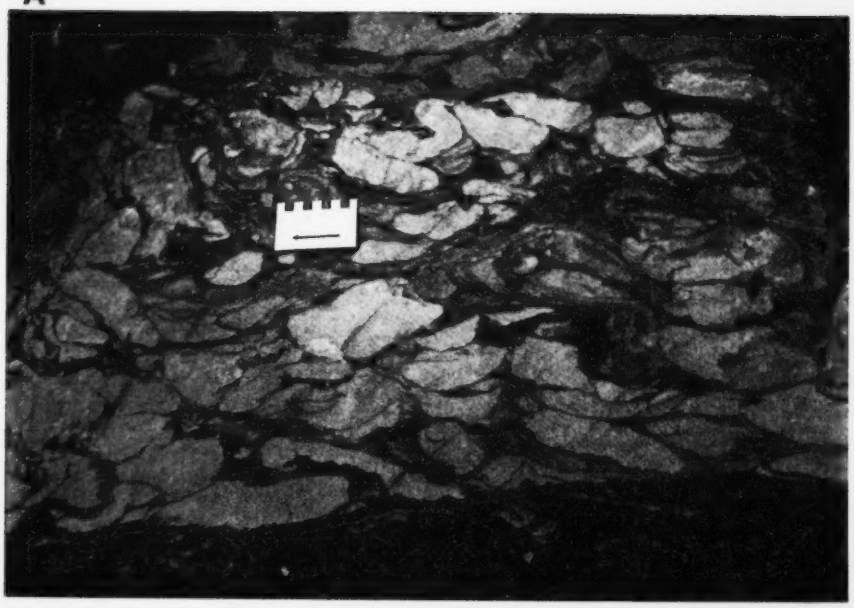
Section 11 is 3 km further downstream and is more complex, displaying lateral variability. Unit 1 at the upstream end, indicated in the stratigraphic log, has >15 m of highly disrupted sediments (Facies G), where little bedding has been preserved. The typical sediment type is sub-rounded clasts of silt in a matrix of clayey silt (53% silt, 47% clay) (Plate 4-7A). This highly disturbed sediment is overlain by unit 2, ~4 m of relatively undisturbed laminated to finely bedded silt and clay (Facies F). In the middle portion of the section >15 m of well stratified silt and clay (Facies F) is in normal fault contact with the disrupted sediment (Facies G). At the downstream end a large clast of well stratified silt and clay (Facies F) occurs within the disrupted sediment (Facies G) (Plate 4-7B).

The uppermost unit at both sections is gravel overlain by sand (Facies H).

Interpretation Sections 10 and 11

All four sediment types (Facies E, F, G and H) represented at sections 10 and 11 are interpreted similarly to those described above; deposition occurred by turbidites, suspension settling, slumps and slides, and downcutting by the Pelly River, respectively. The fine grain size of the laminated silt and clay (Facies F) and the lack of coarse material represent a much lower energy environment than that represented in the Anvil Creek area. However, a major slumping event is suggested by the magnitude of the

A



B

Plate 4-7: 7A: Detail of highly disturbed silt and clay (Facies G) from unit 1, upstream portion of section 11; 7B: Downstream portion of section 11 with a large clast of laminated silt and clay within disturbed sediment (Facies G). Height of section approximately 20 m.

disruption at section 11. Although slumping is common in glacial lakes due to rapid sedimentation (Ashley *et al.*, 1985, Ashley, 1989), it is more likely that the extensive disruption described here was triggered by the melting of supporting ice. Thus even in this distal lake, deposition was over ice.

Confluence Of The Pelly And Macmillan Rivers

The confluence of the Pelly and Macmillan rivers occurs near the maximum extent of the McConnell ice, adjacent to the uplands of the Macmillan Range. Stratigraphic logs for Sections 12 to 15 are shown in Fig. 4-6.

Description Sections 12 to 15

Sections 12 to 15 have a similar stratigraphy. Unit 1 at each section consists of disturbed sediment (Facies G). Unit 1 at Section 12 and 14 consists of a fining upward sequence from stratified diamicton to sand and silt, that is variably disturbed (Facies G). The diamicton is warped into broad folds while the sand and silt is highly disturbed, containing folds and zones of brecciation similar to that described before (Facies G). The lower portions of sections 13 and 15 are covered and only disturbed sand and silt (Facies G) are exposed in unit 1.

Unit 2 at sections 12 to 14 consists of fining upward sequences from silt (88% silt, 12% clay) to silty clay (45% silt, 55% clay). Lower contacts are gradational with the amount of disturbance decreasing upward. Clasts deforming bedding are present and reach concentrations of ~5% in the upper portion of section 12.

In contrast with all the other sections studied, only section 14 appears truncated by sand. This sand (Facies H) reflects the sandy bedload of the Macmillan River.

Interpretation Sections 12 to 15

The deformed sediment (Facies G) and the silt and clay (Facies F) are interpreted similarly to those above; deposition occurs as slump and slide , and as distal deposition in a glacial lake, respectively. The large thicknesses of deformed sediment at the base of these sections again implies deposition on top of ice. Coarse sediment, stratified diamicton in this case, only occurs at the base. The fining upward sequence at each section represents increasingly distal sedimentation in a glacial lake containing icebergs. This is the only area where the sequence fines upward and suggests that there was a lack of coarse material from streams so no deltaic systems prograded in this lake. This suggests that the low elevation of glacial limits resulted in small volumes of material for resedimentation into this lake.

DISCUSSION AND RECONSTRUCTION OF SEDIMENTARY ENVIRONMENT

The distribution of sediment reflects control by several systems: 1) till deposited under ice; 2) diamicton deposited by debris flows in glacial lakes; 3) sorted sediment deposited by meltwater streams; and 4) sediment remobilized and deformed by the melting of underlying ice.

The till (Facies A) and debris flow deposits (Facies B) represent two contrasting types of diamicton. The till formed from a combination of lodgement and meltout processes, below both active and stagnant ice. As interpreted in the Anvil Creek area, much of the stratified diamicton (Facies B)

originated from previously deposited till that was remobilized down valley sides and from bedrock highs. The stratified diamicton (Facies B) is more common than the massive diamicton (Facies A), implying that reworking of till was a major process in this environment.

Interstratified diamicton and sorted sediment (Facies C) represents slightly more distal deposition than the stratified diamicton (Facies B). The presence of massive sand and the abundance of soft sediment deformation structures implies rapid deposition of facies C.

The deposition of coarse gravel (facies D), sand (Facies E) and silt and clay (Facies F) are all, in part, controlled by meltwater streams. The coarse gravel (Facies D) represents the highest energy deposit in the study area and may have originated in two different ways: as a result of isolated events, such as failures from the valley sides or jökulhlaups; or alternately, as sediment gravity flows fed by meltwater from subglacial, englacial or ice marginal positions. Failure from the valley sides could occur when gravel was deposited on stagnant ice by meltwater streams. The ice subsequently melts, causing failure and the sediment accelerates downslope. Jökulhlaups could occur from side valleys from failure of ice or sediment dams. The coarse and apparently rapidly deposited gravel (Facies D) at section 4A could have been deposited by either of these two methods. More commonly, gravel (Facies D) would be deposited in "deltaic" systems. Subaqueous outwash deposits could form where sub or en-glacial tunnels entered lakes (section 8). Meltwater from the surface of the ice would also deposit gravel on the main channels of deltaic cones. The thick sequence of gravel at section 7 indicates lateral streams could deposit significant amounts of coarse gravel.

Deposition of sand (Facies E) occurred on subaqueous cones or deltas and was mainly by turbidity currents, likely from meltwater stream underflow.

The general absence of high angle foreset bedding in the sand (Facies E) suggests the formation of low gradient deltas or cones. The fact that sediments locally grade upward to glaciofluvial gravel (Facies H sections 2 and 3) suggests that the lakes were shallow and in some cases were filled in by a prograding delta system. Based on the limited current indicators presented above, with few being oriented down valley, meltwater streams from the ice front may be unimportant. It could be that meltwater streams were similar to the meltwater channels shown in Plate 4-2, being in a lateral position and then flowing towards the valley center.

Silt and clay (Facies F) represents the most distal sediments in the study area and were deposited by distal turbidity current and suspension settling. They only occur in significant thicknesses in areas where lakes were far from a source of coarse sediment (Safety Pin Bend, and confluence of the Pelly and Macmillan rivers).

The extensive occurrence of disturbed sediment (Facies G) indicates deposition in supraglacial lakes. Melting of supporting ice caused sediments to be remobilized into slump and slide deposits and others to be tilted, folded and faulted. Some of this ice persisted as evidenced by the tilting and faulting locally present in gravel (Facies H) at the top of sections (Plate 4-5).

The two tills separated by sorted sediments at sections 7 and 8 suggest that the ice front was periodically active, even though the regional style of deglaciation suggests that the ice sheet was climaticly dead. This appears to suggest that the readvance had some glaciological control.

Based on the discussion and examples above, a sedimentary environment is constructed to explain Late Wisconsinan sedimentation along the Pelly Valley. A series of lake basins were present, apparently separated by bedrock highs and stagnant ice. Sediments in these lake basins display an

overall transition in grain size from coarser material adjacent to Glenlyon Range (Sections 1 to 9) to finer material within the area of the Yukon Plateaus (Sections 10 to 15). This transition is probably controlled by the amount of glacial material available from adjacent slopes for resedimentation. The sections adjacent to Glenlyon Range, with steep, glaciated slopes, contain the coarsest material, whereas at Safety Pin Bend the terrain is more subdued and material is finer. Adjacent to the steep slopes of the Macmillan Range at the confluence of the Pelly and Macmillan rivers, the low elevation of the glacial limit reduced sediment availability which resulted in a fining upward sequence to be deposited.

Fig. 4-7 shows the complex situation adjacent to the Glenlyon Range where sediments are coarser grained. The importance of resedimented material is demonstrated by the abundant failures from slopes into the lake. Lateral meltwater streams, sub- and englacial streams, side valleys and gully erosion provided sand and silt for sedimentation, commonly on to stagnant ice. As this ice melted subaqueous slumps and kettles formed. As the ice sheet slowly thinned and the lakes transgressed the glacier would likely have kettles on its surface similar to those reported by Clayton (1964). A similar modern analog may be provided by supraglacial lakes associated with stagnant zones of the Malaspina Glacier in Alaska (Gustavson and Boothroyd, 1982).

Within Yukon Plateaus initial sedimentation of coarse material occurred. This likely reflects a source directly from the ice sheet. As the supporting ice melted, slumping and sliding occurred. This was followed by distal sedimentation of fine grained material.

The style of deglaciation of various parts of the valley is problematic, since all sediment was not deposited on to ice. This could indicate that the ice front was periodically calving or floating. Calving is indicated by the presence

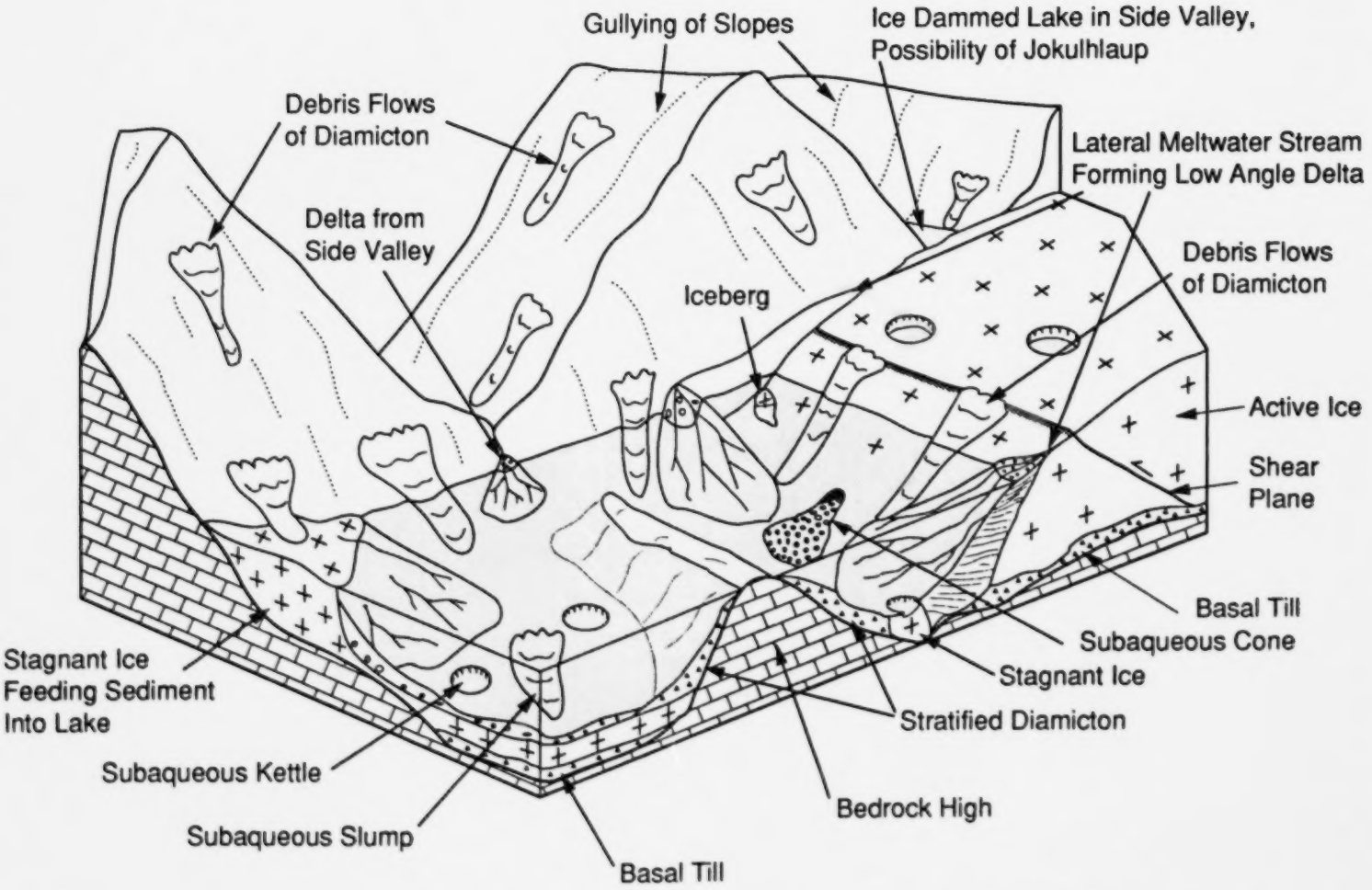


Figure 4-7: Proposed depositional environment of lakes adjacent to the Glenlyon Range.

of dropstones in some of the lake sediments. Calving would also explain the abrupt transition from glacial diamicton to fine grained glaciolacustrine sediments. However, the relatively small size of many of the lake basins limits the volume of ice that can be evacuated.

The distribution of sediments described in this study is similar to published models by Eyles *et al.* (1987), Eyles & Clague (1991) and Shaw (1988). A notable similarity is the abundance of material which was deposited above stagnant ice in a supraglacial lacustrine environment. Lateral facies changes observed along the valley are similar to those inferred by Eyles & Clague (1991). Differences here include that the ice front was occasionally active, that sediments were deposited into several small lake basins rather than one large basin and that diamictons were much more common than suggested by Eyles and Clague (1991).

The deglacial valley fill sediments described along the Pelly River represent complex deposition in supraglacial lakes. Abundant supraglacial lakes formed because of the regional stagnation style of deglaciation. Supraglacial sedimentation has been reported from throughout the Interior System of the Canadian Cordillera, and it likely forms an important component of the second end member of deglacial valley fills in area of regional stagnation.

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CHAPTER 5 - SUMMARY AND CONCLUSIONS

The objective of this study was to document the Quaternary geology of the Glenlyon map area (105 L). In chapter 2 surficial sediments were subdivided into twenty-three units on the basis of their genesis, surface expression, stratigraphic age, texture and modifying process and range in age from Holocene to Early Pleistocene in age. Holocene deposits are common along valley bottoms as alluvial and organic units and along steep slopes as colluvial deposits. Units representing the Late Wisconsinan McConnell glaciation are common throughout the map area. Morainal, glaciofluvial and lesser amounts of glaciolacustrine deposits are present. Units from the Illinoian Reid glaciation and the Early Pleistocene pre-Reid glaciations are rare and only occur above and beyond the limit of McConnell glaciation. Morainal deposits of the pre-Reid glaciation(s) have a very subdued surface morphology. Reid glacial deposits are less subdued and consist mainly of morainal deposits with minor amounts of glaciofluvial deposits.

The stratigraphy and glacial history were discussed in Chapter 2. Deposits from the Reid and McConnell glaciations and the Middle Wisconsinan Interstadial, and a paleosol representing the Koy-Yukon thermal event were identified in section. No deposits examined in section were assigned to the pre-Reid glaciations. The oldest deposits found were at the Bradens Canyon section in the Carmacks map area (115K). Here, unit 1 records cold periglacial conditions at some time prior to Reid ice overrunning the site but still within the Bruhnes normal polarity chron.

Reid deposits are common beyond the limit of McConnell glaciation and rare within it. Abundant deposits from the Reid glaciation are exposed along the Pelly River beyond the limit of the McConnell glaciation. This includes morainal and glaciofluvial deposits at the Bradens Canyon section, glaciofluvial deposits at the Pelly Farm section and glaciolacustrine deposits at

the Granite Canyon section. At Drury Lake, well within the limit of the McConnell glaciation, a thick advance sequence of glaciolacustrine and deltaic sediments capped by a till and deglacial gravel are preserved under McConnell till.

No deposits attributed to the Koy-Yukon thermal event were identified in the study area. However, a truncated paleosol at the Pelly Farm section likely represents pedogenesis during the Koy-Yukon thermal event and is correlative to the Diversion Creek paleosols (cf. Tarnocai *et al.*, 1985; Smith *et al.*, 1986).

Pre-McConnell and post-Koy-Yukon thermal event deposits were identified at three sites: Granite Canyon, Pelly Farm, and Section 26. Mid Wisconsinan organic beds were identified at the Granite Canyon section; a study of insect macrofossils and pollen indicate forested conditions at 36,000-37,000 yr BP, confirming results from the Mayo Indian Village site along the Stewart River (Matthews *et al*, 1990). A low gradient alluvial fan at the Pelly Farm section occurs above a truncated Koy-Yukon thermal event soil and contains cryoturbation features attributed to glacial conditions during the McConnell. At Section 26 a gravel capped by thick sands is preserved under McConnell till. The gravel and some of the sands likely represent interstadial conditions before McConnell ice advanced into the area.

The landforms and sediments of the McConnell glaciation are well preserved, and allow for better reconstruction of conditions than the previous glaciations. The area was affected by the Selwyn and Cassiar lobes of the Cordilleran Ice Sheet which flowed generally westward and northwestward into the map area. A thick sequence of sands below McConnell till at Section 26 suggests rivers aggraded during ice advance into the area. A study of sediments at the Safety Pin Bend section points to an oscillation of the ice front, likely during advance. With many areas as nunataks, flow of the ice

sheet at maximum McConnell was strongly controlled by topography. Deglaciation of the area was rapid and marked by vertical wastage of the ice sheet rather than frontal retreat. Thus many of the upland valleys became ice free first and large lakes formed in them because drainage was blocked.

During the Holocene rivers cut down to their present base level. A minimum age of 9140 +/-540 yr BP (AVEC-484C) on willow from a paraglacial fan gives a minimum age for the establishment of upland vegetation. Streams had cut down to ~25m above present level by 6570 +/-610 (AVEC 483C). A major Holocene event was the deposition of the White River Tephra at 1250 BP (Lerbekmo *et al,* 1975). Its presence in along most of the present flood plain of the Pelly River indicates that rivers had downcut to their present level by this time. Permafrost also invaded the sediments and its growth and degradation also affected the landscape forming pingos, palsas, thermokarst lakes and retrogressive thaw slides.

In chapter 3 the nature of glaciation of Glenlyon Range was examined. Airphoto analysis, identification of erratics, and stratigraphic and geomorphic investigations were used to determine the nature of the McConnell age glaciation in the Glenlyon Range, Yukon Territory. Most of the peaks of the Glenlyon Range were nunataks within the Selwyn Lobe of the Cordilleran Ice Sheet. Airphoto analysis of the configurations of local and Selwyn Lobe moraines indicates that local glaciers did not extend beyond the cirques and made no contribution to the Selwyn Lobe. This is confirmed by the character of sediments examined in sections along Little Sheep Creek and by the distribution of erratics in one of the cirque valleys. Aridity limited local ice growth: there simply was insufficient precipitation to grow large cirque glaciers. The occurrence of extensive ice in the main ranges of the Pelly Mountains and very limited ice in the Glenlyon Range indicates a very steep climatic gradient

over a distance of 100 - 200 km, likely steeper than that which separates the two areas now.

In Chapter 4 the style of sedimentation during deglaciation was examined. Deglacial sedimentation along the Pelly River was complex. Material was deposited in several small lake basins, often on top of stagnant ice. Several sedimentation systems were at work and sediment appears to have been derived from the active ice margin, stagnant ice, marginal streams, and recently deglaciated side valleys and valley sides. Basal till is rare and most diamictons present appear to be from subaqueous debris flows, often from the valley side. Deltaic systems, which generally lack high angle foreset bedding, deposited coarsening upward sequences from clay to sand with minor gravel which in some cases are in gradational contact with gravels. Mass flows deposited coarse gravels by either jökulhlaup style sedimentation or proximal feeder channels on subaqueous cones emanating from meltwater tunnels. Affecting all these systems of deposition was deformation caused by the melting of supporting ice. This caused remobilization and deposition as slump and slide deposites which occur throughout the study area.

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APPENDIX 1 - PARTICLE SIZE DATA FOR MATRIX OF GLACIAL DIAMICTON

Location of sample sites given in Fig. 2-5
Depth indicates depth below present surface as exposed in section.

SITE	SAMPLE NUMBER	LAB NUMBER	DEPTH (m)	% SAND	% SILT	% CLAY
1	24687-T1	30611	10	49.4	37.7	12.9
2	10687-T1	30600	20	38.2	44.3	17.5
2	10687-T2	30601	20	38.2	46	15.8
2	18687-T1	30604	3.5	28.6	52.8	18.6
3	17687-T1	30602	42	48.7	36.7	14.6
3	17687-T2	30603	20	55.8	32.1	12.1
3	19687-T1	30605	60	27.5	61.6	10.9
5	25688-T1	32204	70	40.4	33.6	26
5	25688-T2	32205	40	49.7	32.5	17.8
6	22687-T1	30606	20	49.9	35.4	14.7
6	22687-T2	30607	40	41.7	44.8	13.5
6	21687-T1	30609	35	74	23.5	2.5
6	12688-T1	32193	45	46.2	36.9	16.9
6	12688-T2	32194	45	49.6	36.5	13.9
6	12688-T3	32195	45	47.1	37.4	15.5
6	14688-T1	32196	65	70	25.3	4.7
6	14688-T2	32197	65	56	30.5	13.5
6	14688-T3	32198	65	51.3	35.8	12.9
7	23687-T1	30608	41	42.6	40.1	17.3
7	23687-T2	30610	30	31	48.7	20.3
9	05787-T1	30614	19	45.8	42.9	11.3
9	05787-T2	60615	10	53.6	39.6	6.9
9	05787-T3	60616	3	53.7	39	7.2
10	16788-T1	32222	120	22.8	61.5	15.7
10	16788-T1	32223	114	57.4	27.7	14.9
11	5787-T4	30617	33	48.2	36.3	15.5
12	18788-T2	32225	20	51.2	28.7	20
13	19788-T1	32226	5	51.1	31.7	17.2
14	18788-T1	32224	50	57.4	27.7	14.9
17	07787-T1	30618	43	51.8	37	11.3
17	07787-T2	30619	42	55.1	32.1	12.8
17	03787-T1	30612	12	52.6	33.5	13.9
17	03787-T2	30613	8	53.9	33.4	12.8
17	07787-T3	30920	4	42.2	41.2	16.6
18	09787-T4	30629	70	43.7	38.9	17.4
18	28688-T4	32210	60	42.5	40.7	16.8
18	28688-T5	32211	58	41.2	40.9	17.9
18	08787-T1	30623	50	43.6	40.2	16.2

SITE	SAMPLE NUMBER	LAB NUMBER	DEPTH (m)	% SAND	% SILT	% CLAY
18	08787-T2	30624	40	23.8	47.9	28.3
18	08787-T3	30625	30	9.2	51	39.8
18	09787-T1	30626	27	44.1	40.3	15.6
18	09787-T2	30627	26	9	49.2	41.8
18	09787-T3	30628	25.5	0.8	61.8	37.4
18	28688-T6	32212	20	40.4	41.7	17.9
19	28688-T1	32207	40	49.5	36.1	14.4
19	28688-T2	32208	35	75.5	18.8	5.7
19	28688-T3	32209	28	41.9	43.8	14.3
19	07787-T4	60621	20	39.5	46.1	14.5
19	07787-T3	30620	4	42.2	41.2	16.6
21	29688-T1	32213	60	74.8	19	6.3
21	15787-T1	60633	40	53.1	31.3	15.6
21	30688-T1	32214	40	34	45.5	20.5
21	15787-T6	30637	39	45.6	39.6	14.8
21	15787-T2	30634	39	32.8	51.3	15.9
21	30688-T2	32215	37	45.1	41	13.9
21	15787-T4	30636	35	26.5	51.1	22.4
21	30688-T3	32216	35	34.6	42.1	23.3
21	13787-T1	30630	30	18.6	53.5	27.9
21	14787-T1	30632	30	44.7	38.7	16.6
21	13787-T2	30631	25	25.4	45.2	29.4
21	01788-T1	32217	15	39.9	43.8	16.3
21	01788-T2	32218	15	43.8	41.7	14.5
21	16787-T1	30638	10	54.7	33.5	11.8
22	22688-T1	32203	1	50.7	44	5.3
23	29787-T1	30639	18	37.5	49.3	13.2
24	31787-T1	30640	55	31.2	53	15.8
24	31787-T2	30641	44	22.1	64.7	13.3
24	31787-T3	30642	32	46.3	44	9.7
26	02887-T2	30644	68	33.3	53	13.8
26	02887-T3	30645	66	47.2	42.4	10.4
26	04788-T1	32220	60	13.1	65.6	21.3
26	04788-T2	32221	40	37.4	55.3	7.3
26	02887-T1	30643	4	62	33	5
26	03788-T1	32219	4	49.9	37.4	12.8
27	JJ-20688-S3	32172	1	40.5	44.8	14.7
28	JJ-20688-S2	32171	1	54.8	37.9	7.3

SITE	SAMPLE NUMBER	LAB NUMBER	DEPTH (m)	% SAND	% SILT	% CLAY
29	11887-S1	30571	40	44.4	51	4.7
29	11887-S2	30572	40	51.4	45.8	2.7
29	11887-S3	30573	40	44.3	50	5.7
29	11887-S4	30574	40	59.3	37.2	3.4
29	08887-T1	30648	40	63.8	28.9	7.3
29	08887-T2	30649	35	53.8	37	9.2
29	08887-T3	30575	30	41.9	52.8	5.2
31	06887-T1	30646	45	49.6	42.8	7.5
31	06888-T2	30647	40	63.6	32.8	3.6
32	12887-S1	30579	17	7.31	54.9	37.8
34	10887-T1	30578	14	48.3	43.3	8.4
35	09887-T1	30576	32	36.1	56.2	7.7
35	09887-T2	30577	31	32.4	57.9	9.7
36	JJ-02688-S1	32170	1	46.1	39.2	14.7
37	JJ-18688-S1	32168	9	56.2	32.4	11.4
38	JJ-19688-S1	32169	1	54	36.1	9.9
39	JJ-16688-S1	32166	3	40	41	19
40	JJ-16688-S2	32167	2	42.4	41.6	16.1
41	JJ-11688-S4	32165	10	39.2	46.6	14.2
42	JJ-21688-S2	32174	22	48.2	39.7	12.1
42	JJ-21688-S3	32175	1	58.2	31.2	10.7
42	19789-T1	34840	3	63	30.7	6.3
42	20789-T1	34841	1	58.6	29.5	11.7
43	17789-T1	34839	2	42.9	46.7	10.4
44	JJ-10688-S1	32160	4	66.7	29.1	4.3
45	JJ-11688-S1	32162	3	41.3	43.8	14.9
46	JJ-11688-S2	32163	5	47.6	41.6	10.6
47	JJ-11688-S3	32164	4	45	35	20

APPENDIX 2 - PARTICLE SIZE DATA FOR GLACIOFLUVIAL AND GLACIOLACUSTRINE SEDIMENTS

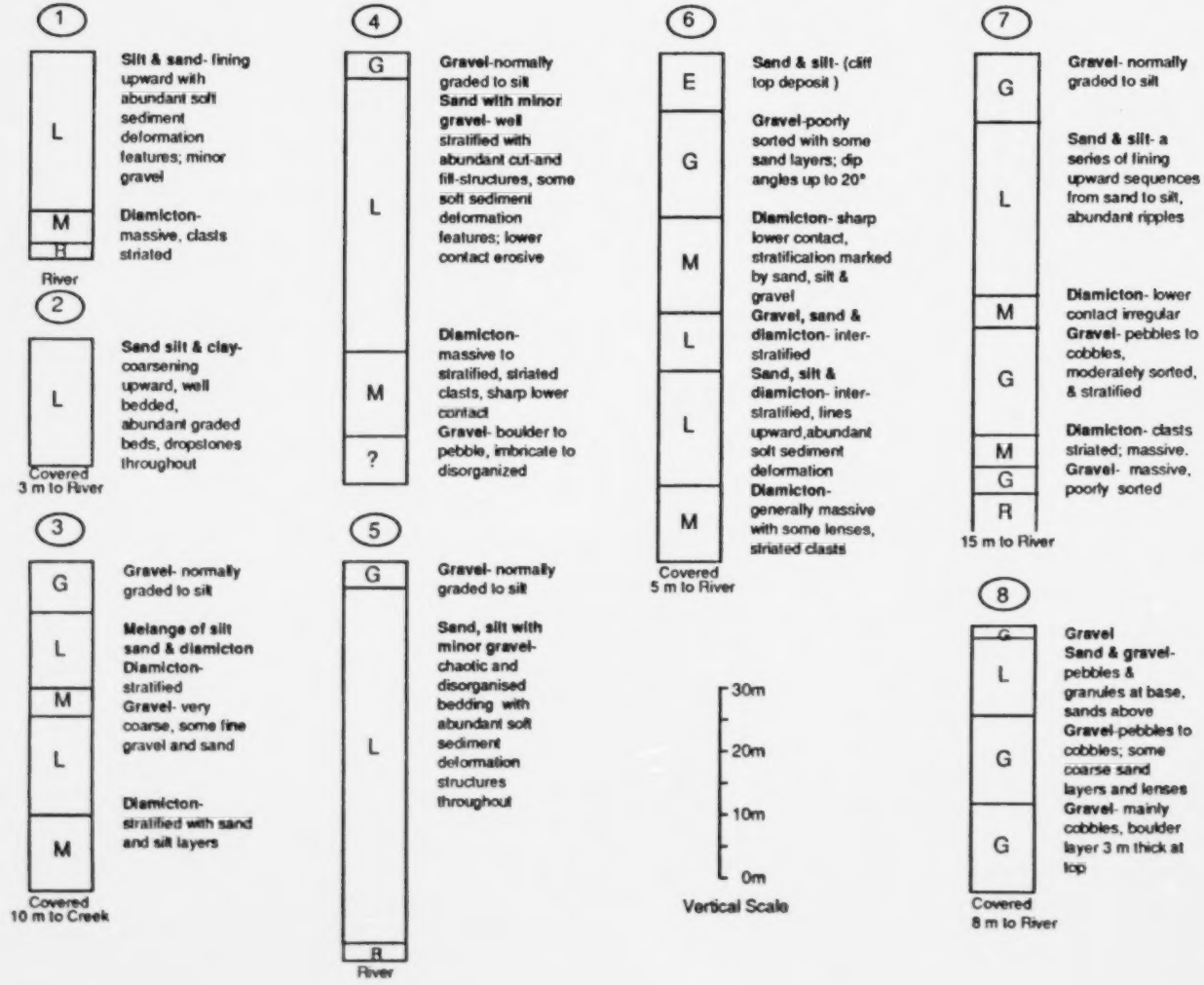
Key for sediment types
GL - Glaciolacustrine
GD - Glaciofluvial deltaic
MG - Matrix of glaciolacustrine and glaciofluvial gravel

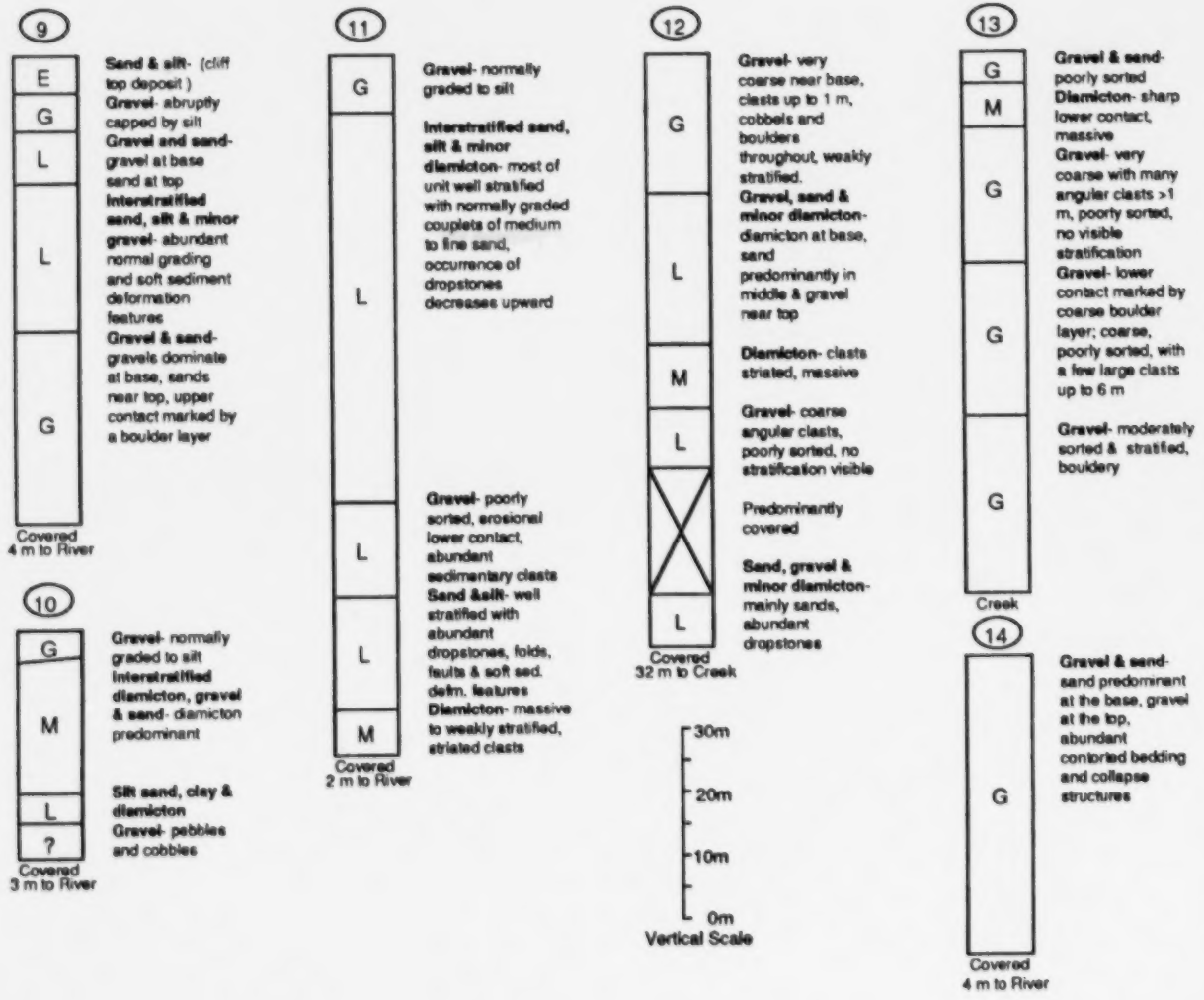
Location of sample sites given in Fig. 2-5
Depth indicates depth below present surface as exposed in section.

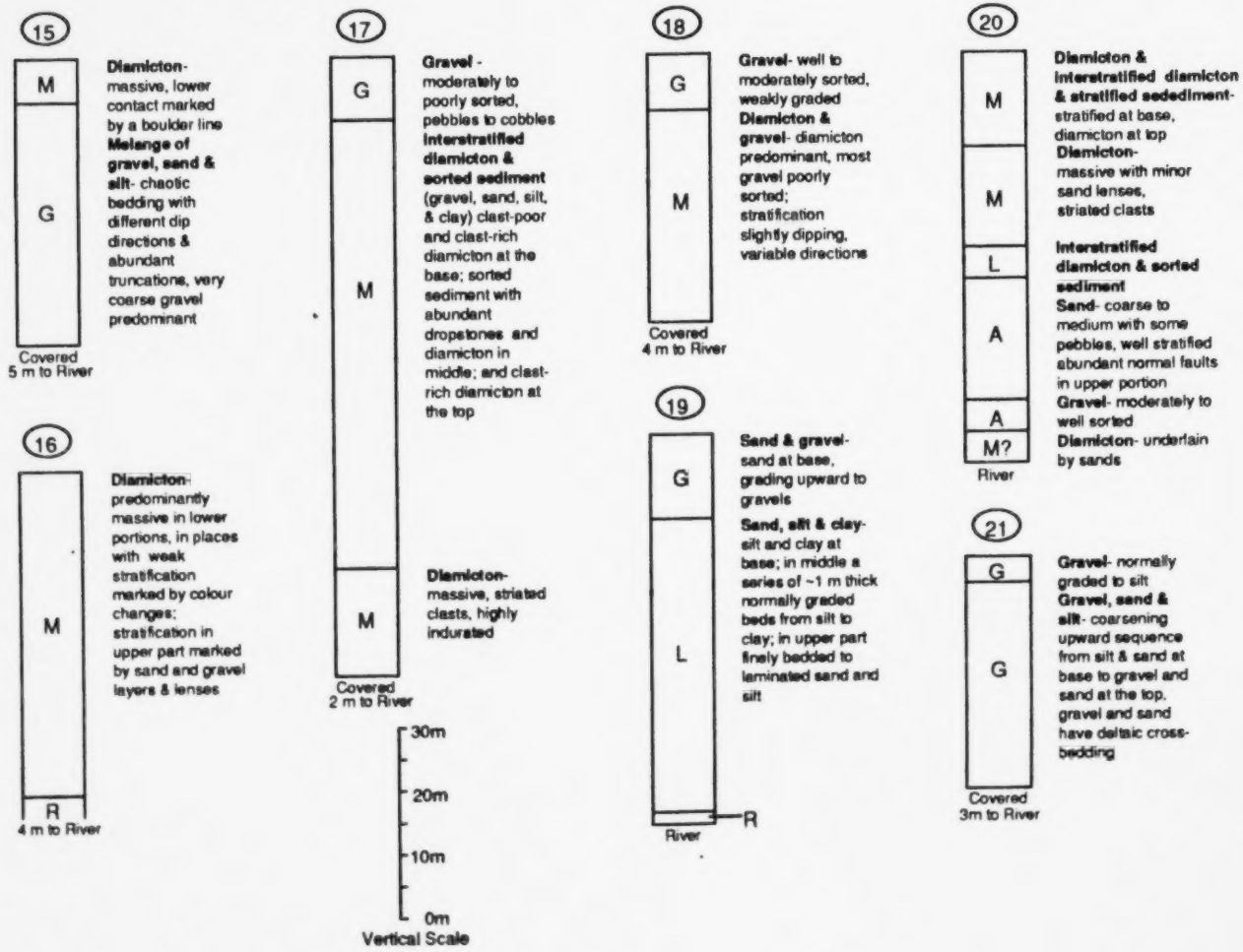
SITE	TYPE	SAMPLE NUMBER	LAB NUMBER	DEPTH (m)	% SAND	% SILT	% CLAY
1	GL	24687-S1	30589	15	0.9	91.5	7.6
2	GL	24687-S2	30591	20	0.5	85.1	14.4
3	GL	17687-S2	30582	40	4.2	63.1	32.7
3	GL	17687-S4	30584	25	7.2	61.3	31.5
3	GL	17687-S5	30585	19	1	69.2	29.8
3	GD	17687-S1	30581	40	63.7	35.6	0.7
3	MG	17687-S3	30583	33	89.1	6.6	4.3
4	GL	23687-S1	30590	16	19.1	79.1	1.8
6	GM	21687-S1	30587	70	60.9	25.4	13.7
6	GL	22687-S1	30588	40	4.6	91.7	3.7
6	GL	21687-S2	30586	50	14.9	82.4	2.7
6	GL	14688-S3	32201	50	17.2	79.7	3.1
6	MG	14688-S1	32199	50	91.3	8.7	N/A
6	MG	14688-S2	32200	50	97.9	2.1	N/A
8	GL	28687-S2	30594	40	1.4	53.6	45
8	GL	29687-S1	30599	38	17	74.5	8.5
8	MG	27687-S1	30592	35	82.2	16	1.8
8	GD	28687-S1	30593	35	89.9	9.1	1
8	GL	28687-S3	30595	37	0.6	92.9	6.5
8	GD	28687-S5	30597	27	92.8	3.6	3.6
8	GD	28687-S6	30598	29	82.6	11.4	6
15	GM	27688-S1	32206	10	94.2	5.8	N/A
20	GL	12787-SI	30557	21	3.6	93.3	3.1
20	GL	12787-S2	30558	20.5	9.3	87.7	3
20	GL	12787-S3	30559	19.5	1	51.2	47.8
20	GL	12787-S4	30560	6	2.3	95.1	2.6
20	GL	12787-S5	30561	10	1.2	91.7	7.1
20	GL	12787-S6	30562	9.5	1.2	94.4	4.4
25	GL	01887-S1	30653	25	0	53.1	46.9
25	GL	01887-S2	30564	25	0.9	96.5	2.6
30	GL	09887-S1	30566	1.5	0	45	55
30	GL	09887-S2	30567	9	0.2	80	19.8
30	GL	09887-S3	30568	21	0.9	82.6	16.5
30	GL	09887-S4	30569	29	0	88.2	11.8
31	GL	07887-S1	30565	5	6	40.1	53.9
33	GL	09887-S5	30570	4	21.2	74.4	4.4

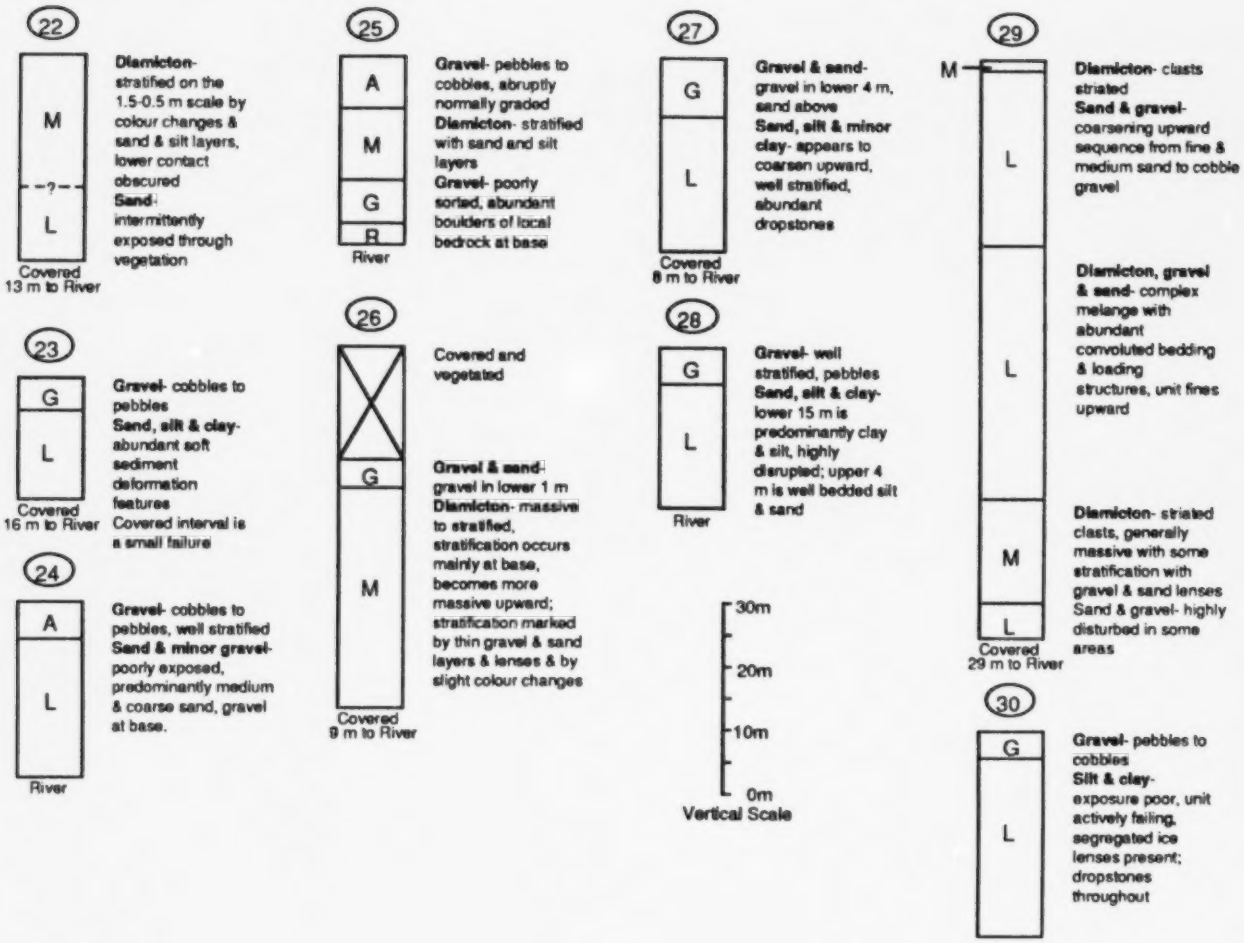
APPENDIX 3 - MEASURED SECTIONS GLENLYON MAP AREA (105L)

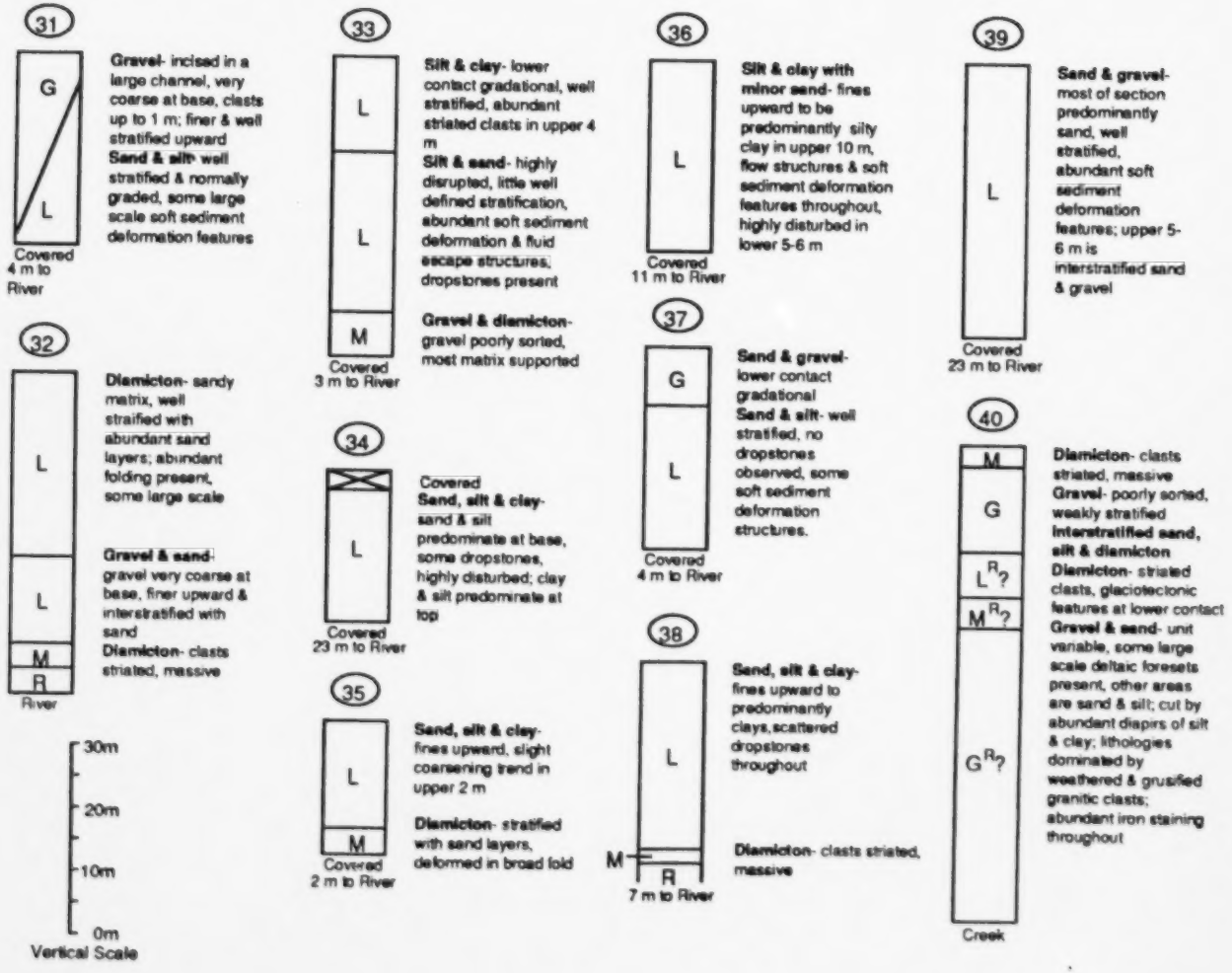
To accompany maps 1786, 1787, 1788 and 1789

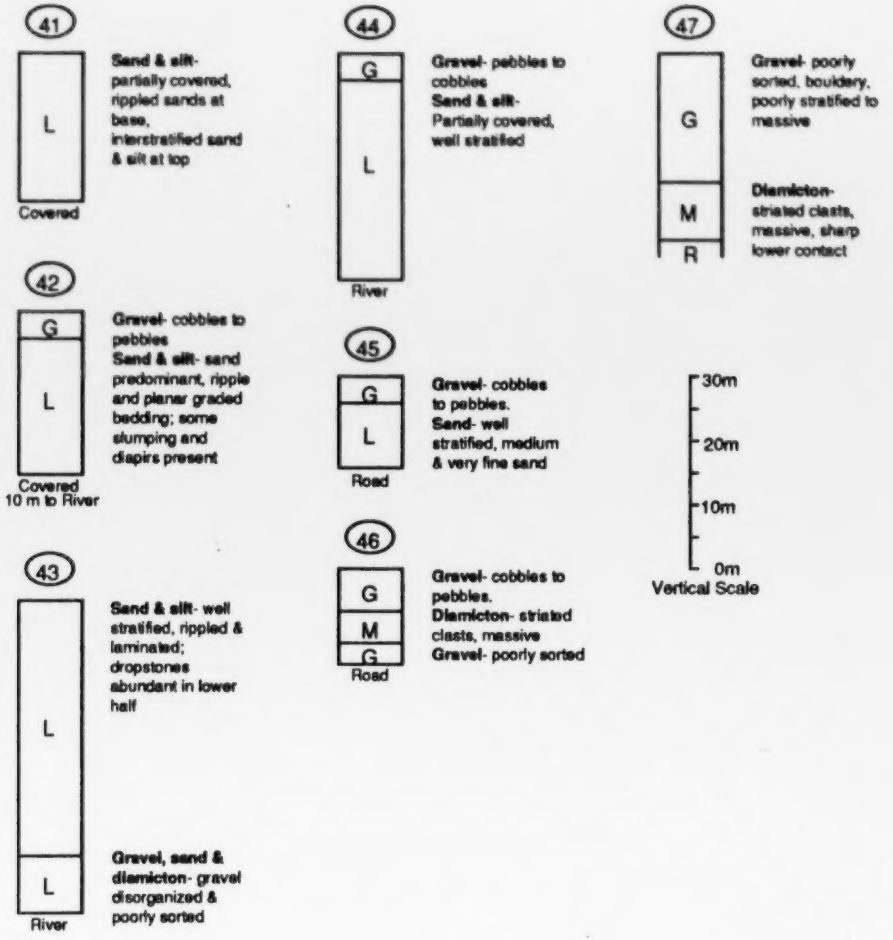

1
L
M
R
River
Silt & sand- fining upward with abundant soft sediment deformation features; minor gravel
Diamicton- massive, clasts striated
2
L
Covered
3 m to River
Sand silt & clay- coarsening upward, well bedded, abundant graded beds, dropstones throughout
3
G
L
M
L
M
Covered
10 m to Creek
Gravel- normally graded to silt
Melange of silt sand & diamicton
Diamicton- stratified
Gravel- very coarse, some fine gravel and sand
Diamicton- stratified with sand and silt layers
4
G
L
M
?
Gravel-normally graded to silt
Sand with minor gravel- well stratified with abundant cut-and fill-structures, some soft sediment deformation features; lower contact erosive
Diamicton- massive to stratified, striated clasts, sharp lower contact
Gravel- boulder to pebble, imbricate to disorganized
5
G
L
R
River
Gravel- normally graded to silt
Sand, silt with minor gravel- chaotic and disorganised bedding with abundant soft sediment deformation structures throughout
6
E
G
M
L
L
M
Covered
5 m to River
Sand & silt- (cliff top deposit)
Gravel-poorly sorted with some sand layers; dip angles up to 20°
Diamicton- sharp lower contact, stratification marked by sand, silt & gravel
Gravel, sand & diamicton- inter-stratified
Sand, silt & diamicton- inter-stratified, fines upward,abundant soft sediment deformation
Diamicton- generally massive with some lenses, striated clasts
30m
20m
10m
0m
Vertical Scale
7
G
L
M
G
M
G
R
15 m to River
Gravel- normally graded to silt
Sand & silt- a series of fining upward sequences from sand to silt, abundant ripples
Diamicton- lower contact irregular
Gravel- pebbles to cobbles, moderately sorted, & stratified
Diamicton- clasts striated; massive.
Gravel- massive, poorly sorted
8
G
L
G
G
Covered
8 m to River
Gravel
Sand & gravel- pebbles & granules at base, sands above
Gravel-pebbles to cobbles; some coarse sand layers and lenses
Gravel- mainly cobbles, boulder layer 3 m thick at top


9
E
G
L
L
G
Covered
4 m to River
Sand & silt- (cliff top deposit)
Gravel- abruptly capped by silt
Gravel and sand- gravel at base sand at top
Interstratified sand, silt & minor gravel- abundant normal grading and soft sediment deformation features
Gravel & sand- gravels dominate at base, sands near top, upper contact marked by a boulder layer
10
G
M
L
?
Covered
3 m to River
Gravel- normally graded to silt
Interstratified diamicton, gravel & sand- diamicton predominant
Silt sand, clay & diamicton
Gravel- pebbles and cobbles
11
G
L
L
L
M
Covered
2 m to River
Gravel- normally graded to silt
Interstratified sand, silt & minor diamicton- most of unit well stratified with normally graded couplets of medium to fine sand, occurrence of dropstones decreases upward
Gravel- poorly sorted, erosional lower contact, abundant sedimentary clasts
Sand &silt- well stratified with abundant dropstones, folds, faults & soft sed. defm. features
Diamicton- massive to weakly stratified, striated clasts
12
G
L
M
L
L
Covered
32 m to Creek
Gravel- very coarse near base, clasts up to 1 m, cobbels and boulders throughout, weakly stratified.
Gravel, sand & minor diamicton- diamicton at base, sand predominantly in middle & gravel near top
Diamicton- clasts striated, massive
Gravel- coarse angular clasts, poorly sorted, no stratification visible
Predominantly covered
Sand, gravel & minor diamicton- mainly sands, abundant dropstones
30m
20m
10m
0m
Vertical Scale
13
G
M
G
G
G
Creek
Gravel & sand- poorly sorted
Diamicton- sharp lower contact, massive
Gravel- very coarse with many angular clasts >1 m, poorly sorted, no visible stratification
Gravel- lower contact marked by coarse boulder layer; coarse, poorly sorted, with a few large clasts up to 6 m
Gravel- moderately sorted & stratified, bouldery
14
G
Covered
4 m to River
Gravel & sand- sand predominant at the base, gravel at the top, abundant contorted bedding and collapse structures


15
M
G
Covered
5 m to River
Diamicton- massive, lower contact marked by a boulder line
Melange of gravel, sand & silt- chaotic bedding with different dip directions & abundant truncations, very coarse gravel predominant
16
M
R
4 m to River
Diamicton- predominantly massive in lower portions, in places with weak stratification marked by colour changes; stratification in upper part marked by sand and gravel layers & lenses
17
G
M
M
Covered
2 m to River
Gravel - moderately to poorly sorted, pebbles to cobbles
Interstratified diamicton & sorted sediment (gravel, sand, silt, & clay) clast-poor and clast-rich diamicton at the base; sorted sediment with abundant dropstones and diamicton in middle; and clast-rich diamicton at the top
Diamicton- massive, striated clasts, highly indurated
30m
20m
10m
0m
Vertical Scale
18
G
M
Covered
4 m to River
Gravel- well to moderately sorted, weakly graded
Diamicton & gravel- diamicton predominant, most gravel poorly sorted; stratification slightly dipping, variable directions
19
G
L
River
R
Sand & gravel- sand at base, grading upward to gravels
Sand, silt & clay- silt and clay at base; in middle a series of ~1 m thick normally graded beds from silt to clay; in upper part finely bedded to laminated sand and silt
20
M
M
L
A
A
M?
River
Diamicton & interstratified diamicton & stratified sedediment- stratified at base, diamicton at top
Diamicton- massive with minor sand lenses, striated clasts
Interstratified diamicton & sorted sediment
Sand- coarse to medium with some pebbles, well stratified abundant normal faults in upper portion
Gravel- moderately to well sorted
Diamicton- underlain by sands
21
G
G
Covered
3m to River
Gravel- normally graded to silt
Gravel, sand & silt- coarsening upward sequence from silt & sand at base to gravel and sand at the top. gravel and sand have deltaic cross-bedding


22
M
?
L
Covered
13 m to River
Diamicton- stratified on the 1.5-0.5 m scale by colour changes & sand & silt layers, lower contact obscured
Sand- intermittently exposed through vegetation
23
G
L
Covered
16 m to River
Gravel- cobbles to pebbles
Sand, silt & clay- abundant soft sediment deformation features
Covered interval is a small failure
24
A
L
River
Gravel- cobbles to pebbles, well stratified
Sand & minor gravel- poorly exposed, predominantly medium & coarse sand, gravel at base.
25
A
M
G
R
River
Gravel- pebbles to cobbles, abruptly normally graded
Diamicton- stratified with sand and silt layers
Gravel- poorly sorted, abundant boulders of local bedrock at base
26
G
M
Covered
9 m to River
Covered and vegetated
Gravel & sand- gravel in lower 1 m
Diamicton- massive to stratified, stratification occurs mainly at base, becomes more massive upward; stratification marked by thin gravel & sand layers & lenses & by slight colour changes
27
G
L
Covered
8 m to River
Gravel & sand- gravel in lower 4 m, sand above
Sand, silt & minor clay- appears to coarsen upward, well stratified, abundant dropstones
28
G
L
River
Gravel- well stratified, pebbles
Sand, silt & clay- lower 15 m is predominantly clay & silt, highly disrupted; upper 4 m is well bedded silt & sand
30m
20m
10m
0m
Vertical Scale
29
M
L
L
M
L
Covered
29 m to River
Diamicton- clasts striated
Sand & gravel- coarsening upward sequence from fine & medium sand to cobble gravel
Diamicton, gravel & sand- complex melange with abundant convoluted bedding & loading structures, unit fines upward
Diamicton- striated clasts, generally massive with some stratification with gravel & sand lenses
Sand & gravel- highly disturbed in some areas
30
G
L
Gravel- pebbles to cobbles
Silt & clay- exposure poor, unit actively failing, segregated ice lenses present; dropstones throughout


31
G
L
Covered
4 m to
River
Gravel- incised in a large channel, very coarse at base, clasts up to 1 m; finer & well stratified upward
Sand & silt- well stratified & normally graded, some large scale soft sediment deformation features
32
L
L
M
R
River
Diamicton- sandy matrix, well straified with abundant sand layers; abundant folding present, some large scale
Gravel & sand- gravel very coarse at base, finer upward & interstratified with sand
Diamicton- clasts striated, massive
30m
20m
10m
0m
Vertical Scale
33
L
L
M
Covered
3 m to River
Silt & clay- lower contact gradational, well stratified, abundant striated clasts in upper 4 m
Silt & sand- highly disrupted, little well defined stratification, abundant soft sediment deformation & fluid escape structures; dropstones present
Gravel & diamicton- gravel poorly sorted, most matrix supported
34
L
Covered
23 m to River
Covered
Sand, silt & clay- sand & silt predominate at base, some dropstones, highly disturbed; clay & silt predominate at top
35
L
M
Covered
2 m to River
Sand, silt & clay- fines upward, slight coarsening trend in upper 2 m
Diamicton- stratified with sand layers, deformed in broad fold
36
L
Covered
11 m to River
Silt & clay with minor sand- fines upward to be predominantly silty clay in upper 10 m, flow structures & soft sediment deformation features throughout, highly disturbed in lower 5-6 m
37
G
L
Covered
4 m to River
Sand & gravel- lower contact gradational
Sand & silt- well stratified, no dropstones observed, some soft sediment deformation structures.
38
L
M
R
7 m to River
Sand, silt & clay- fines upward to predominantly clays,scattered dropstones throughout
Diamicton- clasts striated, massive
39
L
Covered
23 m to River
Sand & gravel- most of section predominantly sand, well stratified, abundant soft sediment deformation features; upper 5-6 m is interstratified sand & gravel
40
M
G
L R?
M R?
G R?
Creek
Diamicton- clasts striated, massive
Gravel- poorly sorted, weakly stratified
Interstratified sand, silt & diamicton
Diamicton- striated clasts, glaciotectonic features at lower contact
Gravel & sand- unit variable, some large scale deltaic foresets present, other areas are sand & silt; cut by abundant diapirs of silt & clay; lithologies dominated by weathered & grusified granitic clasts; abundant iron staining throughout


41
L
Covered
Sand & silt- partially covered, rippled sands at base, interstratified sand & silt at top
42
G
L
Covered
10 m to River
Gravel- cobbles to pebbles
Sand & silt- sand predominant, ripple and planar graded bedding; some slumping and diapirs present
43
L
L
River
Sand & silt- well stratified, rippled & laminated; dropstones abundant in lower half
Gravel, sand & diamicton- gravel disorganized & poorly sorted
44
G
L
River
Gravel- pebbles to cobbles
Sand & silt- Partially covered, well stratified
45
G
L
Road
Gravel- cobbles to pebbles.
Sand- well stratified, medium & very fine sand
46
G
M
G
Road
Gravel- cobbles to pebbles.
Diamicton- striated clasts, massive
Gravel- poorly sorted
47
G
M
R
Gravel- poorly sorted, bouldery, poorly stratified to massive
Diamicton- striated clasts, massive, sharp lower contact
30m
20m
10m
0m
Vertical Scale

135°00'
63°00'
55'
50'
45'
40'
35'
-134°30'
25'
20'
15'
55'
50'

KALZAS RANGE
MOOSE CREEK
RIVER
MACMILLAN
LONE MOUNTAIN
DROMEDARY MOUNTAIN
CRYSTAL CK
CRYSTAL PEAK
DROMEDARY CREEK
DROMEDARY LAKE
LAKE
EARN
EARN

Af Ap Au Ca Cb Cv Gd Gp Gt Gx Lb Mb Mv R R-A

15'
10'
05'
134°00'
63°00'
55'
50'
Mb
Af
Mv
Ca
Au
Gd
Gl
Gx
Cy
A
E
R-A
L A K E
H I L L S
E A R N

Ca
Gx
Mb
Af
Mv
Gd
Lp
Ap
Gt
Cb
R-A
PELMAC
RIDGE
LITTLE KALIZAS LAKE
KALIZAS MOUNTAIN
135°55'
135°50'

18'
10'
06'
135°00'
63°00'
55'
50'
Af
Mv
Ca
Cb
Mb
R-A
KALANG MOUNTAIN
Gd
Lp
Gx
Ap
Gp
Cv
RIVER
CREEK

Mv Gx Gd Gt Mb Af Gp Ca Ap At Au R Lx Cv

WILKINSON RANGE

EARN

EARN

EARN

HILL

GENEVIEVE

PEEL RIVER

PEEL RIVER

PEEL RIVER

MOUNT

40'

35'

L A K E

E A R N

H I L L S

H I L L S

E A R N

Mb
Af
Co
Mv
Gt
Gx
Gd
Au
Gp
Lp
R
Cv
Mv
Mb
Af
Co
Mv
Mb
Af
Co
Mv
Mb
Af
Co

Mv
Mb
RIDGE
Af
Gd
Gx
Gt
Ca
Ap
Gp
Lb
Au
Mb
Mv
Gx
Gp
Mb
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Mb
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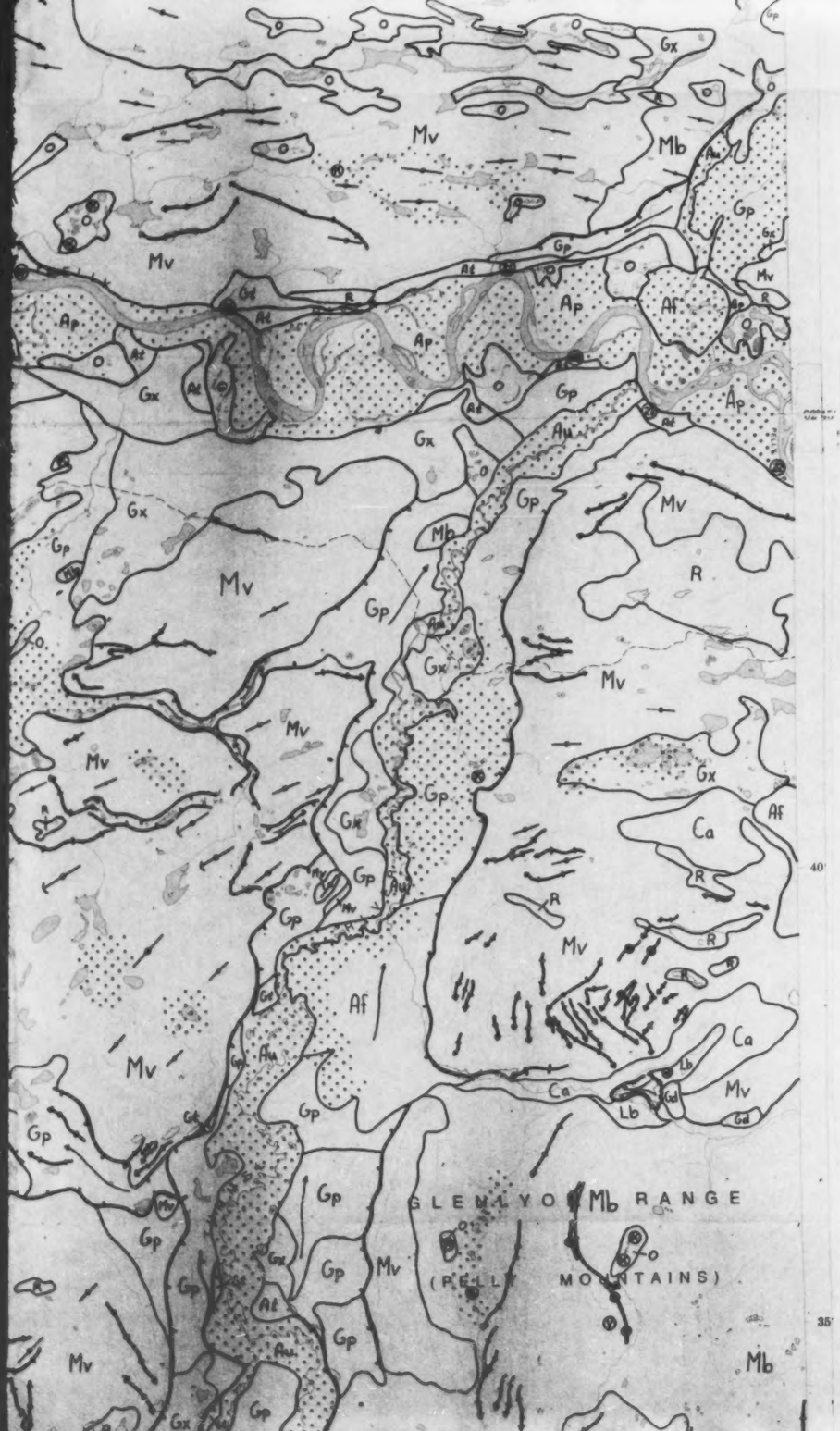
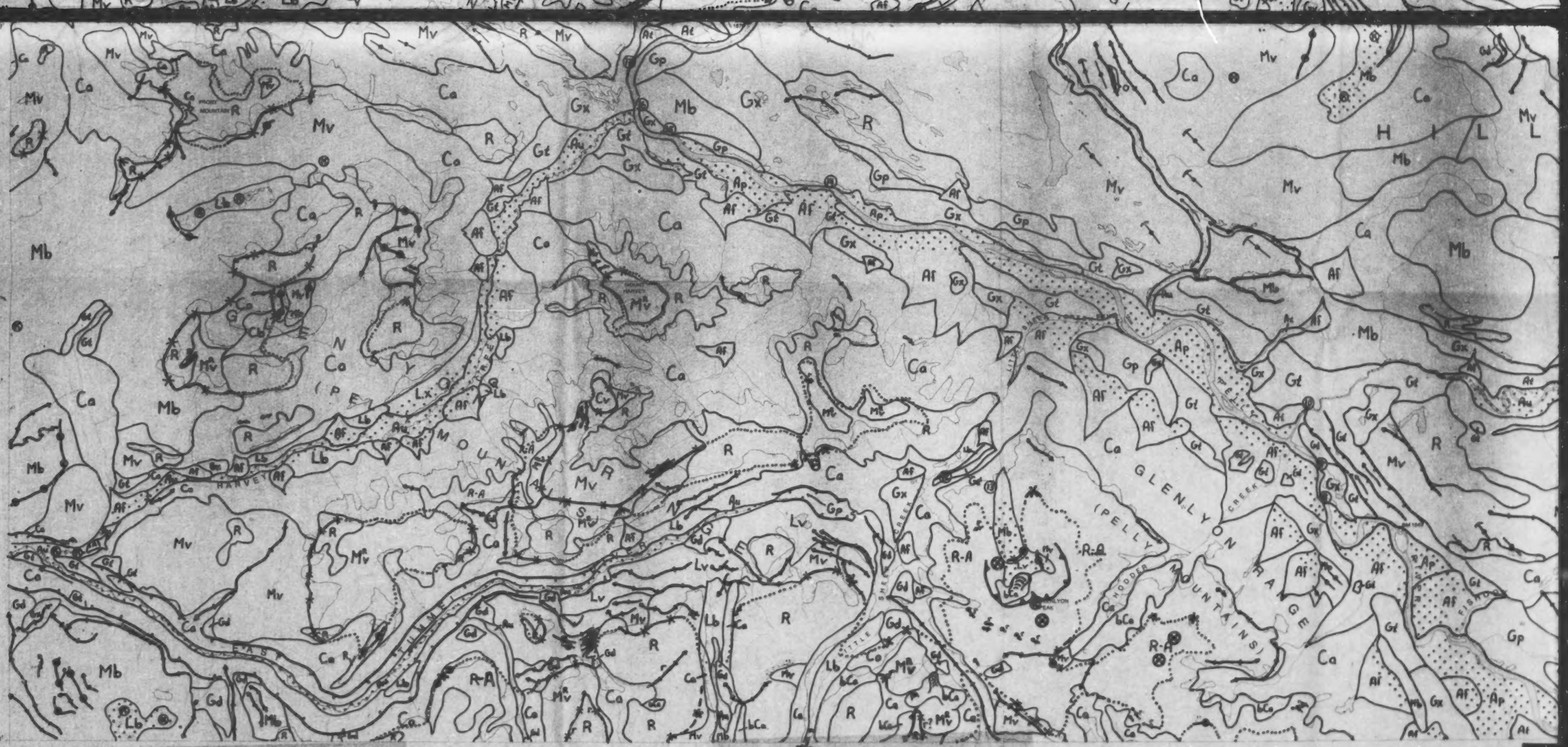
Mb
Mv
Gp
Mb


Mv
Mb
Gx
Gp
Ap
Af
Au
At
R
Ca
Lb
Gd
GLENLYON RANGE
(PELLA MOUNTAINS)



1787A

LOCATION MAP

MAP1787A

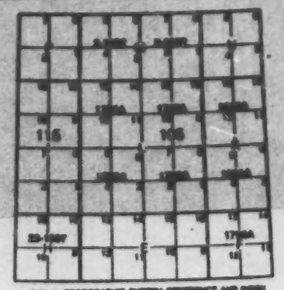
SURFICIAL GEOLOGY

WILKINSON RANGE

YUKON TERRITORY

Scale 1:100 000

Geology by B. Ward and L. E. Jackson, Jr.



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

Kilometres 2 0 2 4 6 8 Kilomètres

105 L NE
105 L NE

1786A

1786A

LOCATION MAP

MAP1786A

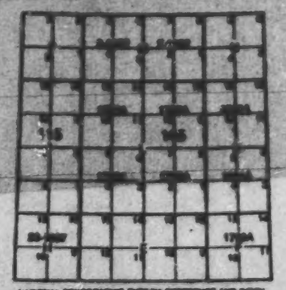
SURFICIAL GEOLOGY

RAGGED LAKE

YUKON TERRITORY

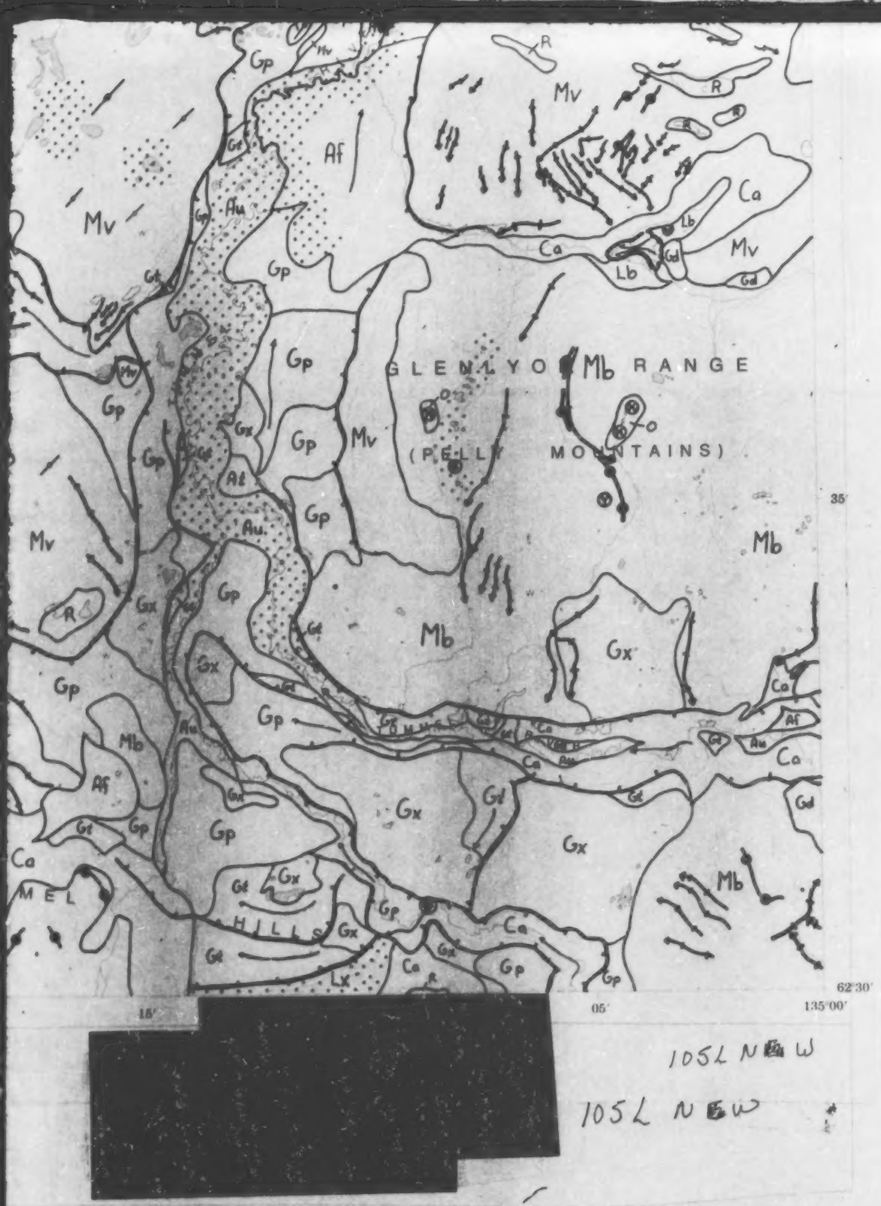
Scale 1:100 000

Geology by B. Ward and L. E. Jackson, Jr.



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO YUKONIAN GEOLOGICAL SURVEY OF CANADA MAPS

Kilometres 0 1 2 3 4 5 Kilomètres



105L NW

105L NW

136°00' 55' 50' 45' 40' 35' 135°30' 25' 20' 15' 10'

62°30' 25' 20'

TADRU LAKE

ESS LAKE

KELLY

TADRU MOUNTAIN

BEAR PEAK

R-A

WEDGE

TATCHUN

CHUCK CREEK

LILLOOET

Mv Mb Gd Gx Lv Lp Ca Gt Af Gp Lx Lb Cv R

135°00'
62°30
15'
10'
05'
25'
20'
Ca
Lx
R
Gx
Gp
Mv
Mb
Lp
Cv
R:A
Af
Gd
Lb
Au
Gt
Ax
Mv
Mb
Gp
Gx
Ca
Af
Gd
Gt
Au
Lb
Ax
R
Cv
Lp
R:A
Mv
Mb
Gx
Gp
Ca
Af
Gd
Gt
Au
Lb
Ax
R
Cv
Lp
R:A
Mv
Mb
Gx
Gp
Ca
Af
Gd
Gt
Au
Lb
Ax
R
Cv
Lp
R:A
CANYON RANGE
(PELLY MTNS)
BEAR FORK
SALMON
RIDGE
CREEK

[redacted]

135°00'
02°30'
45'
40'
35'
134°30'
25'
20'
15'
10'
25'
20'
PASS
CREEK
DRURY
LAKE
ALMON
CR
MOUNTAIN
ESKERS
Mb
Mv
Au
Ca
R-A
R
Gx
Gd
Gp
Af
Lb
Lv
At
Lx
bCa

134°00'
62°30
15'
10'
05'
25'
20'
Af
At
Gp
Mb
Lb
Mv
Ca
Lx
Au
Ap
Gt
Gx
Gd
R-A
R
RANGE
MOUNTAIN
RIVER
RAILWAY

TATCHUN MOUNTAIN

TATCHUN 4862

R-A
AFE PEAK

FRENCHMAN LAKE

H I L L S

Mb
Gp
Af
REEF
Gx
Gt
Au
Mv
Gx
BEARFED
Af
Gp
Gt
Gp
Mv
RA
Mb
Mb
Au
Mv
LITTLE
SALMON
Mv
Af
Ca
Gt
Gd
Mv
Gx
Af
Gd
Af
Gt
Ca
Gp
Au
Af
Gd
Mv
Mb
Mv
Af
Mb
Lp
Mb
Mv
Lp
Gt
R
Au
Lb
Ca
Af
Lx
Gd
Mv
R
Ca
R
Af
Af
Lp
Lp
Au
Lp
Lp
Lp
Lb
Af
Gx
Mv
Mv
Af
Au
Gx
Mb
Gt
Gx
Gx
AF
Gx
Au
Gx
AF
AF
Af
Ca
Mb
Ca
Mv
Mv
R
Mv
Af
Af
Gx
Gt
Mb

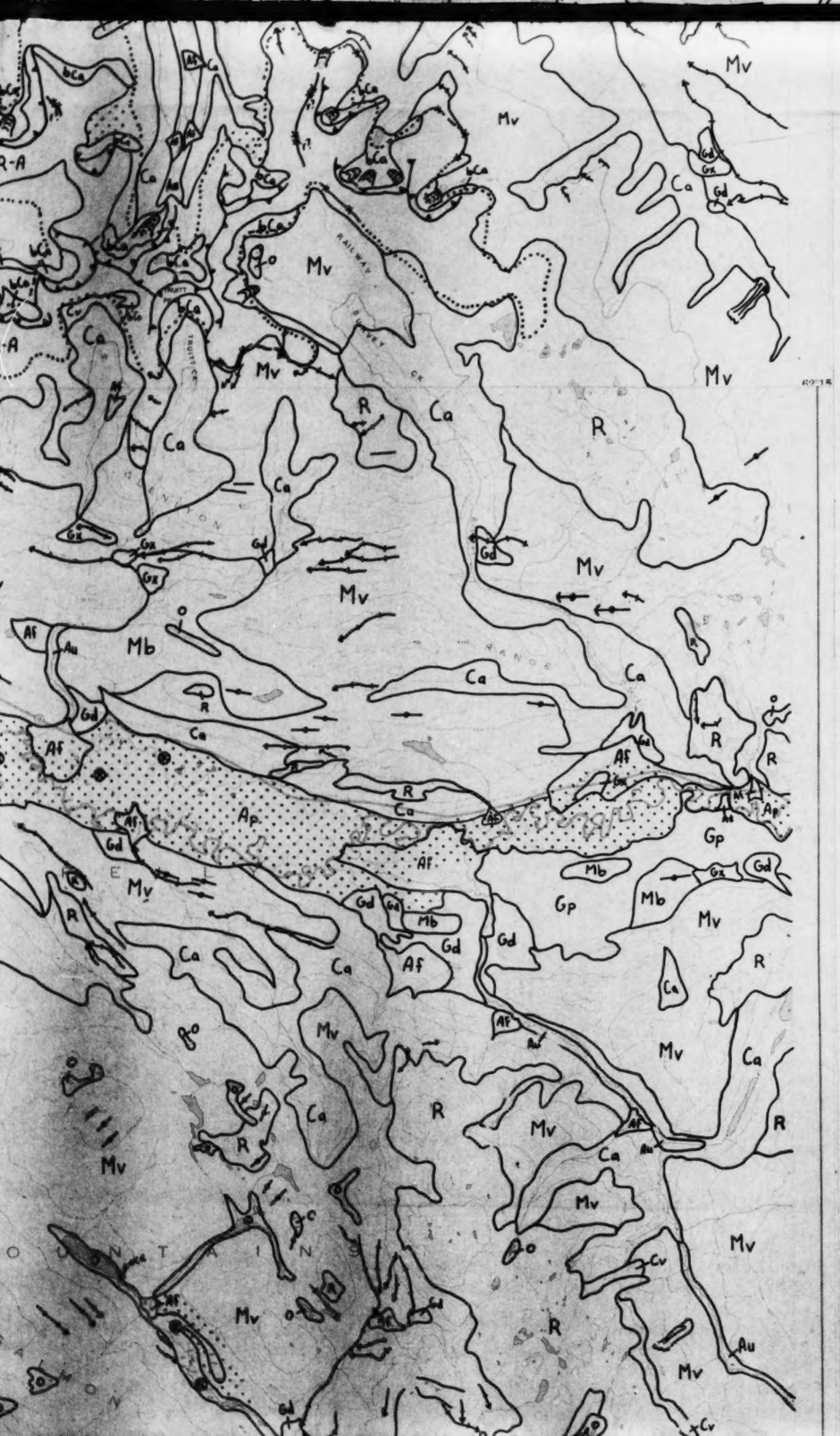
LITTLE SALMON LAKE

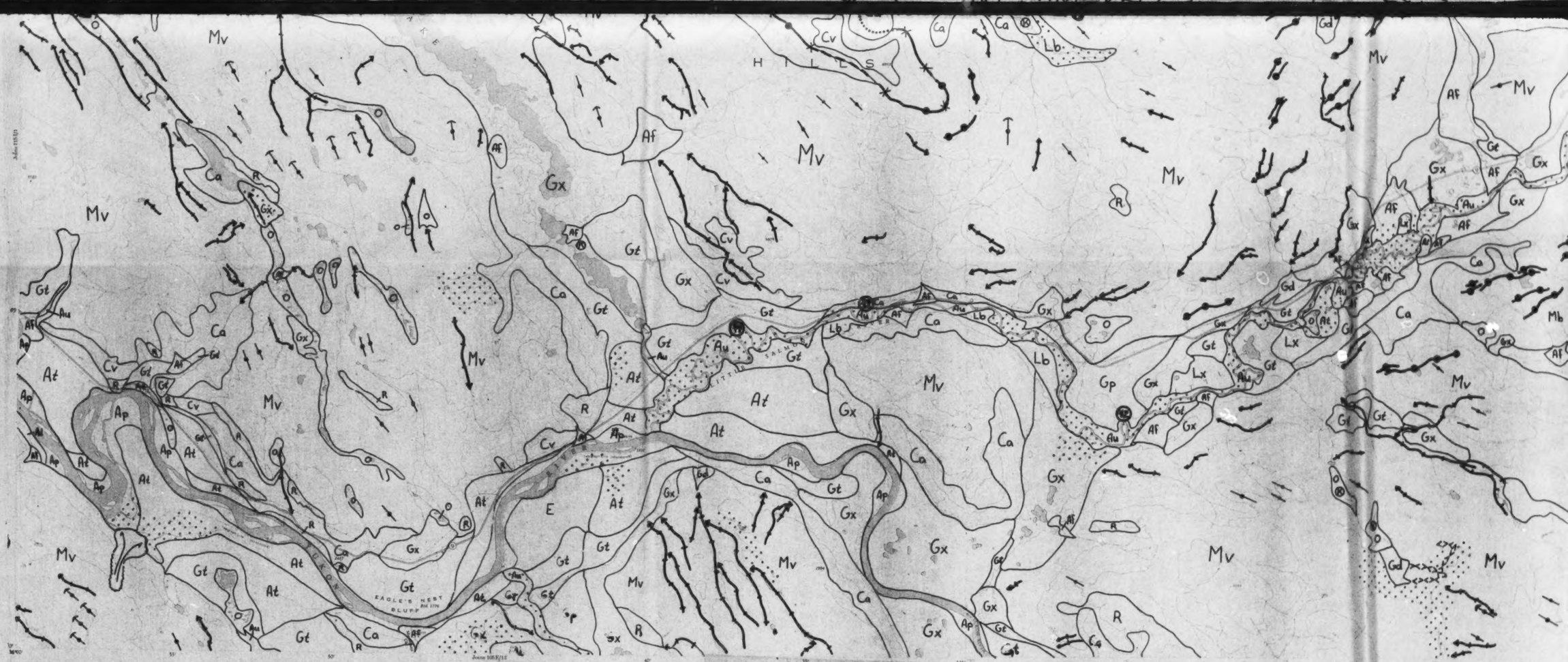
LITTLE SALMON RANGE

SALMON LAKE

BIG SALMON RANGE

MOUNTAIN


Mv
Ca
R
Mb
Af
Au
Gd
Gx
Ap
Gp
Cv
RAILWAY
TRUITT CR
MOUNTAINS



LOCATION MAP

MAP1788A

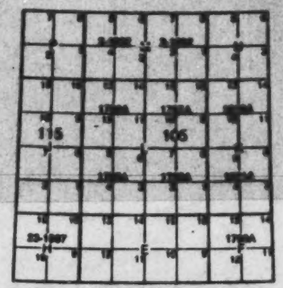
SURFICIAL GEOLOGY

AFE CREEK

YUKON TERRITORY

Scale 1:100 000

Geology by B. Ward and L. E. Jackson, Jr.



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

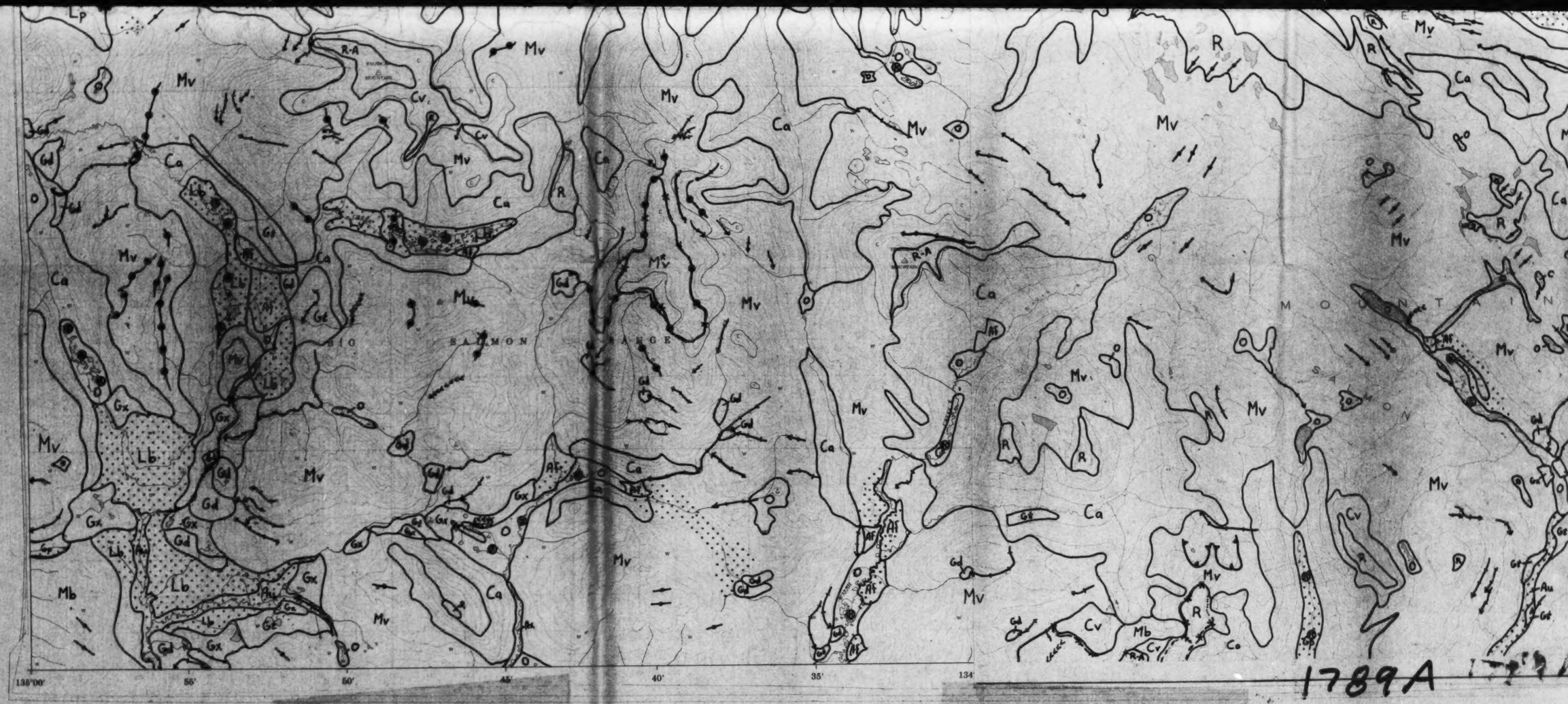
Kilometres 2 0 2 4 6 8 Kilometres

1788A

105 L SW

1788

Lb
Gx
Mv
Af
Au
Lp
Gd
Mb
Ca
Gt
E



1789A

LOCATION MAP

MAP1789A

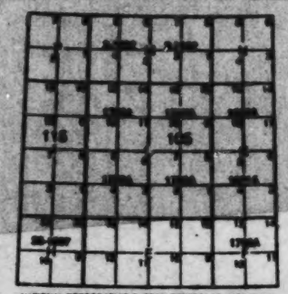
SURFICIAL GEOLOGY

DRURY LAKE

YUKON TERRITORY

Scale 1:100 000

Geology by B. Ward and L. E. Jackson, Jr.



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

Kilometres 2 0 2 4 6 8 Kilometres

Mv
R
Ca
Af
Gd
Mb
Gp
Au
Cv
Gx
MOUNTAIN
SAWON
RANGE
1789A
105°06'E

LEGEND

This legend is common to maps 1786A to 1789A.
coloured legend blocks indicate map units that appear on this map

QUATERNARY

HOLOCENE - POST McCONNELL GLACIATION

O	***ORGANIC DEPOSITS:*** *peat and muck several metres to tens of metres thick, formed predominantly by the accumulation of vegetative material in bogs and fens, depressions and valley bottoms. Permafrost is commonly present within 1 m of the surface in blanket bog; thermokarst collapse and palsa growth are common in bogs and fens*
E	***EOLIAN DEPOSITS:*** *well sorted sand transported and deposited by wind action, greater than 1 m thick and generally forming parabolic and linear dunes*
	COLLUVIAL DEPOSITS: *stony diamicton or rubble resulting from the breakdown of bedrock through physical and chemical weathering and the downslope movement of previously deposited surficial material; variably reworked and transported by gravitational processes such as creep, solifluction, debris flow, snow avalanching, and rockfall*
Cb	***Colluvial blanket sediments:*** *diamicton or rubble; greater than 1 m thick*
Cv	***Colluvial veneer sediments:*** *diamicton or rubble; less than 1 m thick and/or discontinuous*
Ca	***Colluvial apron sediments:*** *bouldery diamicton, poorly sorted sands and gravels forming a wedge-like slope-toe complex of small steep debris flow and avalanche-dominated fans and solifluction deposits ranging from less than 1 m at the upslope limit to 10 m or more in the thickest part of the apron*
bCa	***Rockfall deposits:*** *bouldery, angular rockfall deposits that form aprons up to 10 m or more in maximum thickness along the bases of steep slopes*
	ALLUVIAL DEPOSITS: *gravel to silt size sediments deposited by streams; deposits are commonly stratified and moderately to well sorted, except for some alluvial fan deposits*
Ap	***Floodplain sediments:*** *cobble to pebble gravel capped by sands and silts; greater than 1 m thick; includes lacustrine and organic deposits in abandoned channels and bog and fen areas; floodplain deposits subject to periodic inundation and reworking by floods*
At	***Alluvial terrace sediments:*** *cobble to pebble gravel capped by sands and silts; greater than 1 m thick; underlies one or more benches along the margins of active floodplains*
Af	***Alluvial fan sediments:*** *gravel, sand, silt, and diamicton up to 10 m or more thick; alluvial fans subject to stream avulsion and flooding and, on smaller and steeper fans, inundation by debris flows*
Au	***Alluvial sediments, undivided:*** *floodplains, fans, and terraces that cannot be subdivided at this map scale*

WISCONSINAN - McCONNELL GLACIATION

	GLACIOLACUSTRINE DEPOSITS: *well stratified sand, silt, clay, and minor gravel and diamicton deposited in lakes ponded by glacial ice; sediments may have regular surfaces or have ridged, hummocky, or pitted surfaces caused by meltout of buried glacial ice. They commonly contain segregated ground ice and are affected by contemporary thermokarst collapse and retrogressive thaw flow slides along rivers*
Lp	***Glaciolacustrine plain:*** *sand, silt, and clay with minor dropstones; 5 m or more thick*
Lb	***Glaciolacustrine blanket:*** *silt and clay with minor sand; 1 to 5 m thick*
Lv	***Glaciolacustrine veneer:*** *silts and clays; less than 1 m thick or discontinuous*
Lx	***Glaciolacustrine complex:*** *sand, silt, and clay; hummocky, pitted, and ridged; comprises up to 10 per cent gravel and diamicton layers and lenses and dropstones; usually more than 5 m thick*
	GLACIOFLUVIAL DEPOSITS: *sands, gravels, and minor silts; greater than 1 m thick; deposited by streams flowing from or in contact with glacial ice, including deltas graded to former glacial lake levels. Sorting ranges from good to poor and stratification from thin bedded to massive. Sediments commonly display evidence of syndepositional collapse due to meltout of buried or supporting ice*
Gp	***Glaciofluvial plain and fan sediments:*** *pebble to cobble gravels capped by sands and silts; greater than 1 m thick*
Gt	***Glaciofluvial terrace sediments:*** *pebble to cobble gravels capped by sands and silts; greater than 1 m thick*
Gd	***Glaciofluvial delta:*** *sand, gravel, and minor silt and clay; greater than 5 m thick*
Gx	***Glaciofluvial complex:*** *sand, gravel, diamicton, and minor silts and clay; greater than 5 m thick; forming hummocks, kettles, esker and crevasse-fill ridges; includes minor elements of* Gp *and* Gt
	MORAINAL DEPOSITS: *glacial diamicton, mainly till, generally consisting of a silty sandy matrix containing pebbles, cobbles, and minor boulders; deposited either directly by glacial ice or by gravity flow from glacier ice*
Mb	***Till blanket:*** *greater than 1 m thick but conforming to the underlying topography*

Gd	*Glaciofluvial delta*: sand, gravel, and minor silt and clay; greater than 5 m thick
Gx	*Glaciofluvial complex*: sand, gravel, diamicton, and minor silts and clay; greater than 5 m thick; forming hummocks, kettles, esker and crevasse-fill ridges; includes minor elements of Gp and Gt
	MORAINAL DEPOSITS: glacial diamicton, mainly till, generally consisting of a silty sandy matrix containing pebbles, cobbles, and minor boulders; deposited either directly by glacial ice or by gravity flow from glacier ice
Mb	*Till blanket*: greater than 1 m thick but conforming to the underlying topography
Mv	*Till veneer*: less than 1 m thick or discontinuous; in places contains extensive areas of thin (less than 1 m) and patchy colluvium

ILLINOIAN - REID GLACIATION

$G^{R}d$	*GLACIOFLUVIAL SEDIMENTS*: sand, gravel, and minor silt and clay; greater than 5 m thick; deposited as deltas by meltwater streams entering glacial and proglacial lakes
$M^{R}v$	*MORAINAL DEPOSITS*: glacial diamicton, mainly till, generally consisting of a silty sandy matrix containing pebbles, cobbles, and minor boulders; less than 1 m thick or discontinuous; in places contains extensive areas of thin (less than 1 m) and patchy colluvium

PRE-ILLINOIAN - PRE-REID GLACIATION

$M^{PR}v$	*MORAINAL DEPOSITS*: glacial diamicton, mainly till, generally consisting of a silty sandy matrix containing pebbles, cobbles, and minor boulders; many of the clasts are highly weathered; less than 1 m thick or discontinuous; in places contains extensive areas of thin (less than 1 m) and patchy colluvium

PALEOZOIC TO TERTIARY

R	Volcanics, sediments, metasediments, and felsic intrusives; includes areas of thin colluvial cover blockfields and sorted stone polygons in alpine areas
R-A	Bedrock areas subject to rapid mass wasting processes (rockfall and snow avalanches)

Geological boundary

Cirque

Arête

Streamlined glacial bedform (ice flow direction known, unknown, Reid glaciation)

Moraine

Glacial limits
- McConnell (defined, approximate, assumed)
- McConnell coincident with moraine
- Reid (defined, approximate, assumed)
- Reid coincident with moraine

Esker (flow direction defined, undefined)

Subglacial and proglacial meltwater channel;
- McConnell (large, small, single wall of large channel) arrow indicates flow direction
- Reid (large, small) arrow indicates flow direction

Terrace (marking stages of formation)

Discontinuous organic deposits generally less than 1 m thick

Discontinuous eolian sands or silts

Rock glacier

Landslide (arrow indicates direction of movement)

Open system pingo; collapsed open system pingo

Tor

Cryoplanation terrace

Thermokarst collapse activity

Location of stratigraphic section

Moraine (McConnell glaciation, Reid glaciation)

Pre-Reid (small) arrow indicates flow direction